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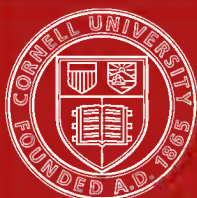
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Essentials of physics and chemistry writ



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G. P. PUTNAM'S SONS, NEW YORK AND LONDON.

ESSENTIALS OF PHYSICS AND CHEMISTRY

WRITTEN ESPECIALLY FOR THE USE OF STUDENTS
IN MEDICINE

BY

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THIRD EDITION, ENLARGED AND REVISED

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TO
MEDICAL STUDENTS
IN RECOLLECTION OF MY OWN STUDENT DAYS
AND IN EARNEST DESIRE TO ASSIST
THOSE ACTIVELY ENGAGED IN THE STUDY OF MEDICINE
THIS VOLUME IS GLADLY
INSCRIBED

PREFACE TO THE THIRD EDITION.

THESE essentials of physics and chemistry are not intended to take the place of such standard text-books as Ganot and Fownes, but simply to aid the student in preparing for "quiz" or examination. In preparing my students for examination, I have felt the need of some such little work that I could recommend to them for a general review or recapitulation of the ground covered in lecture or "quiz." When a student myself, and in active preparation for examination, some such essentials would have been of the greatest assistance, for although having faithfully studied my text-books on physics and chemistry, when taking them up for a final general review I could not help thinking how many shells I must crack to obtain the small amount of meat required. For the time spent in digging out this meat and presenting it in a palatable form, I now feel amply rewarded by the favor with which this book has been received by students,—especially medical students, for whom it was originally written.

This *third* edition has been changed by the addition of new matter and thorough revision of the old, which will, I trust, together with the different form and shape of the book, add to its merits and insure its continued favor with my friends—the students.

150 West 53d St., New York.

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PART I.
PHYSICS.

MATTER.

CHAPTER I.

Physics treats of the phenomena presented to us by matter.

Matter is any thing we can appreciate by our senses, and is made up of *sixty-six elements* or substances that cannot be divided into other substances.

PROPERTIES OF MATTER.

The properties of matter may be divided into two classes :

General.

Specific.

A. *General properties* of matter are those common to all matter, and are six in number, viz. :

a. *Impenetrability*. The property of occupying space exclusively.

b. *Extension or volume*. The space matter occupies.

c. *Form*. The definite shape of matter.

d. *Indestructibility*. The inability to destroy matter, even though it may change its form.

e. *Inertia*. The inability of matter to put itself in motion when at rest or of coming to rest when in motion.

f. *Divisibility*. That property which allows matter to be separated into parts.

B. The *Specific Properties* of matter are those which serve to distinguish one form of matter from another, the following being among the most important of such properties :

a. *Ductility*. That property of matter which admits of its being drawn into a wire.

b. *Malleability*. The ability of matter to be rolled or hammered into sheets.

c. *Tenacity*. Inability of matter to be readily pulled apart.

d. *Hardness*. Matter is hard when it is not easily indented or scratched.

e. *Elasticity*. The tendency of matter to return to its original form or volume when the force that altered its shape ceases to act.

DIVISION OF MATTER.

Matter may be divided into :

Atoms.

Molecules.

Masses.

a. *Atoms* are the smallest divisions of matter, and two or more may unite to form molecules.

b. A *molecule* is the smallest group of atoms that will exhibit the physical and chemical properties of the substance, and cannot be divided without losing these characteristics.

c. A *mass* is a collection of molecules.

Molecules present themselves in three different states, as :

Solids.

Liquids.

Gases.

a. In a *solid state* the molecules are naturally in a fixed condition, and as a consequence solid bodies tend to retain a given form.

b. In the *liquid state* the molecules move freely upon each other.

c. In the *gaseous state* the molecules tend to repel each other or to occupy greater space.

FORCES GOVERNING MATTER.

1. Force controlling atoms.

Chemical affinity, or that force which causes atoms to combine or to remain combined.

2. Forces controlling molecules :

Cohesion.

Adhesion.

Repulsion.

Polarity.

a. *Cohesion* is that force which unites molecules to form masses.

b. *Adhesion* is the molecular force which binds together the surfaces of two or more masses.

Capillary attraction is that form of adhesion which takes place between solids and liquids, as between water and glass.

c. *Repulsion* is that force which causes molecules to occupy more space.

d. *Polarity* is that force which unites molecules to form crystals.

3. Force controlling masses.

Gravitation is the force attracting masses to each other, and is governed by the following law :—

The attraction is directly in proportion to the mass and inversely as the square of the distance.

Gravity is the force exerted by the earth upon a body, and represents weight.

SPECIFIC GRAVITY.

Specific gravity or density is comparative weight.

The standards for comparison are—for *liquids and solids*, water at a temperature of 60° F., and for *gases and vapors*, air or hydrogen.

The principle by which we obtain the specific gravities of substances depends upon the law of Archimedes:—*A body immersed in a liquid loses weight equal to the weight of the liquid displaced.*

CHAPTER II.

SIMPLE MACHINES.

There are six simple machines upon the principles of which all machinery is constructed. They are :

The lever.

The inclined plane.

The wheel and axle.

The screw.

The wedge.

The pulley.

The *lever* is the only machine, the principle of which plays an important part in the human mechanism—the bones representing the levers.

The lever is a bar turning on a pivot. The force used is called the power (P), the object lifted the weight (W), and the pivot the fulcrum (F). There are three kinds of levers :

- a. F being between P and W.
- b. W being between F and P.
- c. P being between W and F.

In the first and second class of levers power is gained and time lost, but in the third class time is gained and power lost.

In all forms of levers the distance between F and the P and W is called the arms of the lever, and *the power is to the weight as the length of the weight arm is to the length of the power arm.*

CHAPTER III.

LIQUIDS.

Liquids are but slightly compressible and according to Pascal's law—*Pressure is transmitted undiminished in all directions with the same force, and at right angles to all equal surfaces.*

It is on the principle of Pascal's law that the hydraulic press is constructed. This consists of two cylinders, the area of the piston of one being much greater than that of the other. Water is driven by means of the piston from the small cylinder into the large one, and the pressure of the water upon the large piston will be as much greater than that upon the small one, as the area of the base of the large piston exceeds that of the small.

1. Means of obtaining specific gravity of solids.

By hydrostatic balance. Weigh the substance first in air, then in water, and divide its weight in air by its loss of weight in water. The result is its specific gravity.

If the solid is lighter than water—divide its weight by its weight added to the loss it causes a heavier body previously weighed in water.

2. Of liquids.

a. *By the specific-gravity bottle.*

Subtract the weight of the bottle from the weight of the bottle filled with water, and then from the weight of the bottle filled with the liquid, and divide the latter by the former. The result is its specific gravity.

b. *By the hydrometer*, which consists of a graduated glass tube loaded at the bottom with mercury so it may sink to a certain depth in fluids, the depth depending upon the specific gravity of the substance.

The instruments are known under different names, as lactometer, urinometer, alcoholometer, etc., the name signifying the kind of liquids for which they are used. The graduation of the instrument differs according as the liquid is heavier or lighter than water, which is usually called 1000. Thus milk has a specific gravity of 1029, urine 1022, both being heavier than water. The last two figures in the specific gravity represent, approximately, the number of grains of solid matter to each fluid ounce of the substance.

CHAPTER IV.

GASES.

In gases the molecules tend to expand or repel each other. *Otto Degarager* first established the fact that gases had weight.

The pressure or weight of the atmosphere at the level of the sea is about fifteen pounds to the square inch, but diminishes proportionally as we ascend.

Torricelli's experiment.

Torricelli first determined the pressure of the atmosphere by taking a glass tube sealed at one end, filling it with mercury, and inverting it by placing the open end covered with the thumb in a vessel of mercury.

He found by this experiment that the mercury in the tube remained about thirty inches above the level of the mercury in the vessel, and the weight of this mercury represented the pressure of the atmosphere to be in the proportion of fifteen pounds to the square inch.

The Torricellian vacuum is the space above the mercury in the tube.

Pascal determined that the height of the mercury in the tube really did depend upon the pressure of the atmosphere, for performing the same experiment on a high mountain, he found the mercury did not remain so high.

BAROMETERS.

Barometers are instruments used for measuring atmospheric pressure.

Many of them are based on the principle of Torricelli's experiment—the pressure of the atmosphere being measured by the height of a column of mercury.

MERCURY BAROMETERS.

The simplest form of a mercury barometer consists of a Torricellian tube about 32 inches in length, filled with and inverted into a basin of mercury. This tube is furnished with a graduated scale divided into tenths of inches, so as to enable the observer to readily detect slight fluctuations in the height of the mercury column. At ordinary temperatures and at the level of the sea the column of mercury will measure about 30 inches.

BAROMETRIC CORRECTIONS.

Corrections have to be made in mercury barometers for :

Temperature.

Elevation.

Capillarity.

State of weather.

a. *Temperature.* Heat causes an expansion of the mercury and a rise in the barometer, while cold has the opposite effect.

b. *Elevation.* At the level of the sea the column of mercury measures about 30 inches, but falls about one tenth of an inch for every 87.2 feet of ascent. On account of the change of temperature and diminished density of the atmosphere as we ascend, the barometric fall is not strictly uniform.

c. *Capillarity* causes the mercury to adhere to the sides of the tube.

d. In dry *weather* the atmosphere is dense, and conse-

quently the pressure on the mercury causes it to stand higher than it does in wet weather, when the air is rarer and contains more aqueous vapor.

A storm can usually be predicted by the fall in the barometer.

BAROMETRIC VARIATIONS.

The barometer does not stand at the same height at all latitudes. It increases from the equator to 40° latitude, where it reaches its maximum height of 30.04 inches, and then diminishes from there toward the poles.

There are also daily variations in the barometer, most marked at the equator, where it reaches its maximum height at 10 and its minimum at 4 o'clock.

AIR BAROMETERS.

Besides fluid barometers there are air barometers, *Aneroid's* being a good example.

This consists of a thin metallic box, exhausted of air, the top of which is so thin that it yields readily to alterations in the pressure of the atmosphere. These alterations are transmitted by levers to an index which indicates the pressure on a scale.

LAW OF GASES.

a. *Boyle's law: The volume of a gas is inversely as the pressure.*

b. *The rapidity with which gases mix is inversely as the square root of their density.*

c. *The density of a gas is directly as the pressure.*

d. *Law of Avogadro. Equal volumes of gases at the same temperature contain the same number of molecules.*

SPECIFIC GRAVITY OF GASES.

Weigh the same volume of air and the gas and divide the weight of the gas by that of the air. The result is the specific gravity of the gas.

AIR PUMPS.

The principle of the air pump depends upon the expansive or repulsive property of gases.

We take away a portion of air and the remainder expands so as to fill up the whole space.

In this way the air becomes greatly rarefied, but an absolute vacuum cannot be produced.

In *Sprengel's* air pump which depends upon the principle of converting the space to be exhausted into a *Torricellian vacuum*, falling mercury passes the aperture of the vessel to be exhausted of the gas.

The gas, as it were, is entangled in the falling mercury and in this way a nearly complete vacuum is produced.

It is on the principle of Sprengel's air pump, that traps in water pipes are syphoned, thus leaving the pipes free to allow the passage of sewer gas.

this is to be avoided by putting in suitable plumbing arrangements.

CHAPTER V.

SOUND.

Impressions which the mind receives through the organ of hearing is called sound. For the production of sound it is necessary that the object producing it should be set in vibration and that it be surrounded by media such as air, water, etc., to carry these vibrations to the ear.

Velocity of sound. In the air sound travels at the rate of about 1100 feet per second. As temperature increases the velocity of sound about one foot per second for every degree of rise, therefore sounds travel more rapidly in summer than in winter. Sound travels in water about four times faster than it does in air.

Echo is the reflection of sound from any surface. If the sound and its echo reach the ear within one sixteenth of a second they seem as one, hence an echo is not appreciated unless the surface producing it is more than thirty-five feet from the source of the sound.

Pitch is the acuteness of sound, and depends entirely upon the rapidity of the vibrations—the greater the number of vibrations the higher the pitch. Sixteen vibrations per second produces the lowest and about 33,000 the highest number of vibrations appreciable to the ear.

Intensity of sound is its loudness, and depends upon the properties of the sonorous bodies and the media by which the sound is carried.

The rarer the media the less intense will be the sound.

Quality of sound is its peculiarity which distinguishes it from other sounds, and depends upon the physical properties of the sonorous body.

HEAT.

CHAPTER VI.

Theories.

1. *Emission theory*: Heat is considered an imponderable fluid which surrounds all molecules, and the entrance of this fluid into substances causes heat, and its egress cold.

2. *Undulatory theory*: Heat is due to a rapid vibratory movement of the molecules of any substance. That all space is filled with an imponderable ether, which hot bodies set in rapid vibration, thus communicating a more rapid vibration to the molecules of adjacent substances.

This theory is the one generally adopted.

TEMPERATURE.

Heat causes all substances to expand; hence by the different expansive qualities of liquids, solids, and gases, we can measure temperature.

Temperature is the greater or less extent a substance tends to impart sensible heat to other substances.

THERMOMETERS.

Thermometers are instruments used for measuring temperatures, and whose principle depends upon the contraction and expansion of substances. They usually consist of a glass tube and bulb filled with some fluid substance, and then hermetically sealed and graduated.

But beside the liquid thermometers, air and solid (pyrometers) thermometers are also constructed.

Liquid thermometers are generally used—mercury and alcohol being the best suited for this purpose. Mercury, because it boils only at a very high temperature, and has a nearly uniform rate of expansion; and alcohol, because it does not freeze even at the lowest temperatures.

MERCURY THERMOMETERS.

In constructing an ordinary mercury thermometer, two fixed points are determined for graduation—viz. :

- a. Boiling point of water at the level of the sea.
- b. Freezing point of water.

As these two temperatures are constant and the expansion of mercury is nearly uniform, the graduation of the thermometer is accomplished by dividing the space between the freezing and boiling points of water into an equal number of parts called degrees.

The size of these degrees differs in various countries.

In this country the *Fahrenheit* scale is used—freezing point 32° , boiling point 212° .

In France and on the Continent generally, the *Centigrade* scale—freezing point taken as 0° , and boiling point 100° .

In some portions of Germany the *Reaumur* scale is chiefly used—the freezing point being 0° , while the boiling point is taken at 80° .

CONVERSION OF DEGREES.

1. Fahrenheit to Centigrade.

$$(F - 32^{\circ}) \frac{5}{9} = C.$$

2. Fahrenheit to Reaumur.

$$(F - 32^{\circ}) \frac{4}{9} = R.$$

3. Centigrade to Reaumur.

$$\frac{4}{5} C = R.$$

4. Centigrade to Fahrenheit.

$$\frac{9}{5} C + 32 = F.$$

5. Reaumur to Fahrenheit.

$$\frac{9}{4} R + 32 = F.$$

6. Reaumur to Centigrade.

$$\frac{5}{4} R = C.$$

ALCOHOL THERMOMETERS.

Alcohol thermometers are used for determining low temperatures only, for alcohol boils at 78° C., and as it nears the boiling point it expands very irregularly, thus destroying its accuracy for high temperatures. As mercury freezes at -40° C., and alcohol does not freeze at the lowest temperatures, it is here that alcohol thermometers are found so useful.

They are graduated by means of comparison with the mercury thermometer at different degrees of temperature.

AIR THERMOMETERS.

Air thermometers are so constructed that they contain both air and fluid, the principles of which are based on the expansion of air by increase of temperature. This expansion is noted by the rise and fall of a colored liquid in the tube of the thermometer. The graduation of the scale is made by comparing the position of the fluid with the indications of a mercury thermometer at equal temperatures.

Thermometers may be:

Delicate.

Accurate.

- a. A *delicate* thermometer is one that measures rapidly very small changes of temperature.
- b. A thermometer is *accurate* when it indicates the changes of temperature correctly.

PYROMETERS.

Pyrometers are instruments used for measuring very high temperatures. They are various in kind.

- a. Some are made of metals that melt at a known temperature.
- b. Others depend upon the principle of the air thermometer.
- c. Still others on the electric thermometer—higher the temperature the better the conductivity.
- d. While others on the expansive property of certain substances at very high temperatures.

CHAPTER VII.

EXPANSION.

1. *Of solids.*

Solids expand in three dimensions.

- a. Linear.
- b. Superficial.
- c. Cubical.

The *co-efficient* of expansion is the expansion due to the rise of temperature from 0° to 1° C. The co-efficient of expansion in solids varies to a marked degree, and from this fact many applications are made.

Thus in the *compensation pendulum* the distance between the centre of oscillation and the centre of suspension remains constant at all temperatures by properly using metals with different degrees of expansibility, in its construction.

2. *Of liquids.*

The *co-efficient* of expansion of a liquid is the increase of the unit of volume for a single degree.

With an increase of temperature there is an increase of volume. In water, however, if the temperature fall below 4° C., it expands till the freezing point is reached.

Hence the maximum density of water is at 4° C.

3. *Of gases.*

The *co-efficient* of expansion of a gas is its increase of volume for 1° C.

This co-efficient is nearly uniform for all gases at all degrees of temperature.

Gases expand $\frac{1}{273}$ of their volumes for each degree of Centigrade.

CHAPTER VIII.

FUSION.

Fusion is the passage of a body from the solid into the liquid state.

Every substance begins to fuse at a certain temperature, and that temperature remains the same until fusion is complete.

All substances that expand on passing from the solid to the liquid state, as the great majority do, any increase in pressure will raise the melting point. The reverse is true in all substances—such as ice—that contract during fusion.

LATENT HEAT.

Latent heat is that heat which causes *change of state* or fusion, and is not indicated by the thermometer. Thus if one pound of water at 80° C. be mixed with one pound of ice at 0° C., the result will be water at 0° C. Hence it takes as much heat to melt one pound of ice as will raise one pound of water 80° C. Therefore, 80° C. is called the latent heat of water.

As it requires a certain amount of heat not indicated by the thermometer to turn a solid into a liquid, so it does to convert a liquid into a vapor.

The *latent heat of evaporation or steam* is 540° C., and this heat has to come from surrounding substances, such as heat produced by rapid combustion, etc. Hence evaporation produces cold, and by appropriate apparatus water, mercury, etc., can be frozen by it.

For example, if ten pounds of water at 10° C. be mixed with one pound of steam at 100° C., the temperature of the mixture would be $67^{\circ} + \text{C.}$

$10 \times 10 = 100$ —Total number of degrees of temperature in the ten pounds of water.

$100 \times 1 = 100$ —Temperature of the steam.

540—Latent heat of steam.

740—Total number of degrees.

$740 \div 11$ (the number of lbs. of both water and steam)
 $= 67^{\circ} +$ the temperature of the mixture.

During solution a quantity of heat becomes latent. It is on this principle of fusion that artificial cold is produced.

In passing from a solid to a liquid state a certain amount of heat is required, and the extraction of this heat from surrounding substances lowers their temperatures.

Chemical affinity accelerates fusion, hence acid and a salt or ice and salt acting in this way are better freezing mixtures than a salt or ice alone would be.

Crystals. Fluids which pass slowly into the solid state usually assume regular geometrical forms called crystals.

CHAPTER IX.

VAPORS.

Vapors are æriform fluids into which volatile substances are changed by the absorption of heat. Vapors are transparent and usually colorless.

Vaporization is the rapid passage of a liquid into the gaseous state.

Evaporation is the slow production of vapor from the free surface of a liquid.

Under ordinary conditions liquids pass but slowly into the gaseous state, but in a vacuum all volatile liquids are immediately converted into vapors.

Heat also hastens vaporization.

Saturated vapors. When a vapor is so dense that any increase of vaporization or pressure, or any decrease of temperature, will cause a portion of it to assume a liquid state, the vapor is said to be *saturated*.

The higher the temperature the more vapor it takes to reach the point of saturation.

Tension. The pressure exerted by a gas is called its tension. The tension of a gas is measured by the pressure it exerts on a column of mercury, and is expressed in millimetres. It is obtained experimentally by evaporating gases at different temperatures in the Torricellian vacuum. Increase the temperature and the tension of a gas is increased proportionally.

Boiling is the rapid production of bubbles of vapor in

the mass of liquid itself. Boiling takes place when the tension of its vapor is equal to the pressure of the atmosphere, hence any increase in the pressure will raise the boiling point, and any diminution in the pressure will lower the boiling point.

The former fact is made use of in *Papin's digester*.

The boiling point is the temperature at which a liquid boils.

EVAPORATION.

Evaporation is aided by :

- a. Heat.
- b. Dryness of surrounding atmosphere.
- c. Increase of surface.
- d. Renewal of atmosphere.

LIQUEFACTION OF VAPORS AND GASES.

Liquefaction of vapors and gases is accomplished by means of

- a. Cold.
- b. Pressure.
- c. Chemical affinity.

Distillation is an example of liquefaction of vapors by means of cold. All gases such as hydrogen, nitrogen and "laughing gas" can be liquefied by pressure.

SPHEROIDAL CONDITION.

When a drop of water is thrown upon a red-hot surface, as iron, it does not boil or rapidly evaporate, but forms a globule that rotates rapidly over the iron. This is called *spheroidal state* and is due to the globules resting upon a cushion of its own vapor produced by the heat radiating from the hot surface to its under surface. Many liquids have a spheroidal state.

CHAPTER X.

HYGROMETRY

Hygrometry is determining the quantity of aqueous vapor contained in a given quantity of air.

The air is never saturated, but the ratio of the quantity of aqueous vapor to the atmosphere when saturated is called the *hygrometric state*.

There are a number of instruments made for determining this state, called *hygrometers*.

These are :

Chemical hygrometers.

Condensing “

Absorbing “

Psychrometers.

a. *Chemical hygrometers* are based on the property that some substances have of absorbing all the water in the air passed through them.

The substance, such as the chloride of calcium, having been weighed before and after the passage of the air through it, the difference in weight represents the amount of aqueous vapor present.

b. *Condensing hygrometers* are based upon the fact that if the temperature of the atmosphere is lowered, at a certain degree the point of saturation will be reached, and as a result moisture will be deposited.

This temperature at which the air is saturated is called the *dew-point*.

Comparing the temperature of the surrounding atmosphere and the dew-point, and dividing the tension of the atmosphere at dew-point by the tension of the surrounding air at the given temperature, will give the hygrometric state of the air.

For example :

Temperature of the air = 15° C.

“ “ dew-point = 5° C.

Tension of the air at 15° C = 12.69 mm.

“ “ “ 5° C = 6.53 “

$\frac{6.53}{12.69} = 0.5$, the hygrometric state of the air. In other words, the air would be half saturated with moisture.

c. *Absorption hygrometers* are based upon the property which some organic substances have of elongating when moist, and shortening when dry.

d. The *psychrometer*, or *wet-bulb hygrometer*, is based upon the fact that a fluid evaporates more rapidly in the air, in proportion as the air is drier, and consequently the temperature of the fluid falls in the same proportion.

The instrument consists of two thermometers, the bulb of one covered with wet muslin.

The nearer the air is to being saturated, the nearer the two thermometers will indicate—the wet-bulb thermometer always indicating the lower temperature.

The absolute amount of moisture in the atmosphere is greater in summer than in winter, and at its maximum about six o'clock in the morning. It varies, however, much with the temperature from day to day. The dryness of the air increases with the distance from the sea, and usually with the altitude.

CHAPTER XI.

TRANSMISSION OF HEAT.

Heat is transmitted by :

Radiation.

Conduction.

Convection.

a. *Radiated heat* is that which is transmitted to a body from the source of heat without affecting the temperature of the intervening medium, and *its intensity is inversely as the square of the distance, and directly as the temperature of its source.*

Bodies that transmit radiated heat readily are called *Diathermanic*, while those that stop radiated heat, *Athermanic*. Bodies that absorb the most heat are the best radiators, the two properties being equal.

b. *Conducted heat* is that which is transmitted in the mass of the body itself. Bodies conduct heat with very different degrees of facility. Metals are the best conductors, while organic substances and liquids are poor conductors. Gases conduct heat very little if at all.

c. *Convected heat* is that which is transmitted in liquids. When liquids are heated at the bottom, ascending and descending currents are produced by the heated layers becoming less dense and rising while the denser and colder layers above sink to the bottom. This method of transmitting heat is called *convection*.

REFLECTION OF HEAT.

The laws governing the reflection of heat are like those of light. (*See chapter on light.*)

Some bodies have much greater reflecting power than others. Metals have the greatest and lamp-black the least.

White bodies reflect heat well but absorb little; the reverse is true of black substances.

CHAPTER XII.

CALORIMETRY.

Calorimetry is the measure of the quantity of heat a body loses or gains during change of state or temperature.

Quantities of heat in substances are expressed by the extent of their power to raise the temperature of a known quantity of water.

A *Thermal unit* is the standard of comparison for quantities of heat, and is the amount of heat necessary to raise one pound of water 1° C.

Specific heat is the quantity of heat it takes to raise different substances to the same temperature, and is determined in three ways:

- a. By melting ice.
- b. By mixtures.
- c. By cooling.

The *melting-ice method* is based upon the fact that it takes to melt one pound of ice 80 *thermal units*. This gives a standard for comparison, as some substances will take more thermal units than others to melt the ice.

By mixtures. A known weight of the substance whose specific heat is required is heated to a certain temperature and then immersed in water whose quantity and temperature are known. From the temperature of the water after mixing, the specific heat is determined.

For example: If a pound of mercury at 132° F. be poured into a pound of water at 32° , the temperature will

be 35.25° —that is, the water is heated 3.25° and the mercury is cooled 96.75° . Then $96.75 : 3.25 :: 1 : (0.033)$ the specific heat of mercury,—1 representing the specific heat of water.

The *cooling method* is based upon the fact that bodies of different specific heat will occupy different lengths of time in cooling through the same number of degrees. Those that have the greatest specific heat will take the longest to cool. Water and fluids in general have greater specific heat than metals.

The specific heat of water is taken as *unity*.

The specific heat of substances increases with the temperature, and especially as they near their fusing point or change of state.

CHAPTER XIII.

SOURCES OF HEAT AND COLD.

Sources of heat :

1. *Mechanical.*

Compression.

Friction.

Percussion.

Heat due to percussion is not the result of compression, but to a vibratory motion given to the molecules.

2. *Physical.*

a. Solar radiation.

b. Terrestrial heat.

c. Electricity.

d. Change of state.

At a certain depth below the surface of the earth there is a constant temperature ; below this the temperature increases on the average of 1° C. for every ninety feet of descent.

3. *Chemical.*

a. Combustion.

b. Animal heat.

c. Vegetable heat.

The *heat* of combustion depends upon the *quantity*, while the *temperature* upon the *rapidity*, of the combustion.

Vegetable heat is more marked in plants at the time of blossoming when oxidation accompanies the process.

/ The process of *vegetation* in general is not accompanied by heat, for it is not an oxidation. x

Under the influence of the sun's rays the green parts of the plant decomposes the carbonic acid in the atmosphere into oxygen and carbon which unite with the elements of water to form cellulose, sugar, starch, etc. To effect this, heat is required which is stored up in the plant and reappears during combustion of wood, coal, etc., arising from its decomposition.

SOURCES OF COLD.

- a. Change of state.
 - b. Expansion of gases.
 - c. Radiation.
- Especially nocturnal radiation.

CHAPTER XIV.

MECHANICAL EQUIVALENT OF HEAT.

Heat is the result of motion, and it is found in all cases in which motion is the direct producer of heat, that mechanical force is consumed.

By numerous experiments it has been found that the *mechanical equivalent* of heat is 772 foot-pounds Fahrenheit scale, or 1390 foot pounds Centigrade scale.

In other words, heat and mechanical energy are convertible, and heat requires for its production, and produces by its disappearance, mechanical energy in the ratio of 772 foot-pounds for every thermal unit.

WORK OF ENGINES.

Multiply together the mean pressure on the piston, the area of the piston, and the length of stroke, the result will equal the *working power* of the engine.

This work is compared to *horse power*, which represents 550 *foot-pounds* raised one foot per second.

A *foot-pound* is the work necessary to raise a pound a foot high.

LIGHT.

CHAPTER XV.

Theories :

1. *Emission theory.* This theory assumes that all luminous bodies emit an imponderable substance which, penetrating the eye, acts upon the retina, causing vision.

2. *Undulatory theory.* This theory assumes that all space and substances are filled with luminiferous ether, and the luminosity of any body is due to the rapid vibratory movement of its molecules, thus setting in motion this ether, which in turn, acting upon the retina of the eye, causes vision.

The undulatory theory is the one usually adopted.

PROPAGATION OF LIGHT.

Bodies may be :

Luminous.

Transparent.

Translucent.

Opaque.

a. *Luminous bodies* are those that admit light.

b. *Transparent bodies*, those that transmit light so objects can be distinguished through them.

c. *Translucent bodies*, those that transmit light imperfectly, so that objects are not distinguishable through them.

d. *Opaque bodies* are those that do not transmit light. A *luminous ray* is the direction of the line in which light is propagated.

A *pencil of light* is a collection of rays.

Rays of light may be :

- a. Parallel.
- b. Divergent.
- c. Convergent.

A *homogeneous medium* is one whose chemical composition and density are the same in all parts. In homogeneous mediums, light is propagated in straight lines.

SHADOWS.

Shadow is the space behind an opaque body upon which light is thrown.

Penumbra is the dark space around the true shadow of an object, and is due to the light coming from a source greater than a single point.

VELOCITY OF LIGHT.

The *velocity of light* has been obtained by means of astronomical observations in noting the difference in time of occultation of one of Jupiter's moons when the earth is on opposite sides of its orbit.

This difference has been found to be 16' 36'', which represents the time it takes light to travel across the earth's orbit, and gives for its velocity nearly 190,000 miles a second.

CHAPTER · XVI.

INTENSITY OF LIGHT.

The following law governs the intensity of light :

The intensity of light is inversely as the square of its distance from the source of light.

Photometers are instruments for measuring the relative intensities of light.

The sperm candle burning two grains per minute is taken as the standard for this measurement.

Most photometers, as *Rumford's* and *Bunsen's*, are made upon the principle that to obtain equal shadows light must be of the same relative intensity. Therefore, by placing the sources of light nearer or farther away from the object casting the shadows, until they—the shadows—are equal, the intensity of the light is determined by the law that the intensity of light varies inversely as the square of the distance.


Thus if one light is a foot away and a second light two feet away from the object casting equal shadows, the light two feet distant has four times the intensity of the one only a foot away.

CHAPTER XVII.

REFLECTION OF LIGHT.

The reflection of light is governed by the following law :

The angle of reflection is equal to the angle of incidence, both rays being in the same plane and perpendicular to the reflecting surface.



By drawing a perpendicular to the reflecting surface at the point where the rays meet it, the *angle of incidence* is the angle these rays make with the perpendicular, while the *angle of reflection* is the angle reflected rays make with the perpendicular.

The intensity of the reflecting power of a body increases with the degree of polish, and diminishes with the obliquity of the incident ray.

REFLECTING SURFACES.

Mirrors are bodies with polished surfaces which show by reflection objects presented to them. The image is the place where the objects appear.

The surfaces of mirrors are :

Plane.

Curved.

I. *Plane mirrors.* In plane mirrors the image is formed behind the mirror at a distance equal to that of the object forming it, and on the perpendicular let fall from this object

to the mirror. The image is *erect*, *virtual*, and *equal* in size to the object forming it.

A *virtual image* is one formed by the prolongation of the reflected rays, and not by these rays themselves.

A *real image* is one formed directly by the reflected rays, and not by their prolongation.

Multiple images are formed by proper arrangement of several mirrors, as for example in the kaleidoscope.

II. *Curved mirrors.* Curved mirrors may be :

Spheroidal.

Parabolic.

A. *Spheroidal mirrors.* The *centre of curvature* is the centre of the sphere of which the mirror forms a part.

The *principal axis* is the line drawn from the centre of curvature to the centre of the mirror.

The *secondary axis* is a line drawn from the centre of curvature to any point on the mirror.

The *focus* is the point at which the reflected rays meet.

The *principal focus* is the point where reflected parallel rays meet.

The *conjugate focus*, the point where other than parallel reflected rays meet.

Spheroidal mirrors are :

Concave.

Convex.

a. In *concave mirrors* which tend to *converge* all reflected rays, the principal focus is situated midway between the centre of curvature and the mirror.

The position of the image depends upon the relation of the object to the mirror.

1. If the object is at such a distance that the rays from it are parallel, the image will be situated at the principal focus—*real*, *smaller* than the object, and *inverted*.

2. If the object is beyond the centre of curvature, the image will be *real, inverted, smaller* than the object itself, and situated between the centre of curvature and the mirror.

3. If the object is between the centre of curvature and the mirror, but nearer the centre of curvature, the image will be *real, inverted, larger* than the object, and beyond the centre of curvature.

4. If the object is between the centre of curvature and mirror, but nearer the mirror, the image will be *erect, virtual, and larger* than the object.

b. In *convex mirrors*, all reflected rays tend to *diverge*; whatever be the position of the object in relation to the mirror, the image is always *virtual, erect, and smaller* than the object itself.

B. Parabolic mirrors.

In *parabolic mirrors*, when the light is placed at the principal focus, the reflected rays are nearer parallel than they are in the simple concave mirrors. The light thus reflected maintains its intensity for a greater distance, for it is the divergence of the rays that diminishes the intensity of light.

Parabolic mirrors are used as head-lights in engines, for lantern reflectors, etc., on account of the reflected rays being parallel, and hence maintaining their intensity.

SPHERICAL ABERRATION.

When concave mirrors are large the rays that are reflected from near the edges meet the axis of the mirror nearer the mirror than those that are reflected from the central portions. As a result, the image is not precise, or there is *spherical aberration* by reflection.

CHAPTER XVIII.

REFRACTION.

Refraction of light is the bending of the ray of light in passing from one medium to another.

In passing from a denser to a rarer medium the ray is bent from a perpendicular drawn to the surface of the medium at the point of emergence, but toward the perpendicular in passing from a rarer to a denser medium.

There is in refracted light an *angle of incidence and refraction*.

If a perpendicular be drawn to the surface separating the two media at the point where the rays enter it, the *angle of incidence* is the angle made by the ray and the perpendicular; and the *angle of refraction* is the angle made by the prolongation of the perpendicular and the bent ray as it passes through the second medium.

The incident and refracted rays are in the same plane and perpendicular to the surface separating the two media.

Most substances only refract the incident ray once, but some crystalline bodies cause *double refraction*.

The *index of refraction* is the ratio between the sines of the incident and refracted angles.

To find the *angle of refraction* of any substance, divide the sine of the angle of the incident ray by the index of refraction, and the result will be the sine of the refracting angle.

For example. In the diamond say the angle of incidence is 45° ; its sine would be .70711. The index of refraction is 2.75. Thus, $.70711 \div 2.75 = .257$, the sine of the angle of refraction which corresponds to an angle 15° .

When a luminous ray passes from a greater to a less refracting medium, at a certain obliquity of the ray the angle of incidence is so great that the refracted ray emerges parallel to the separating surface, and the *critical angle* is the angle this oblique ray makes with the perpendicular. Any greater obliquity of the incident ray will cause *total refraction* and none of the rays will pass out of the first medium.

MIRAGE.

Mirage is an optical illusion by which inverted images are seen as if below ground or in the atmosphere. It is a phenomenon of refraction and due to the unequal density of different layers of air when they expand by contact with the heated soil—the least dense rays being the lowest.

CHAPTER XIX.

TRANSMISSION OF LIGHT.

Light may be transmitted through :

Media with parallel faces.

Prisms.

Lenses.

1. When light is transmitted through media with *parallel faces* the emergent rays are parallel to the incident rays.

2. A *prism* is any transparent medium between faces inclined to each other. Any ray of light passing through a prism is refracted twice in the same direction, once in passing into the prism and then again on emergence.

The *angle of deviation* is the angle this emergent ray makes with the incident.

3. *Lenses* may be considered as made of a number of prisms. Lenses are named from their shape :

Convex.

Plano-convex.

Concave.

Plano-concave.

Diverging concavo-convex.

Converging concavo-convex.

The curved surfaces of lenses are arcs of circles.

The *focus* of a lens is the place the refracted rays meet.

The *real focus* is that formed on the opposite side of the lens from the luminous rays.

The *virtual focus* is that formed at the same side of the lens as the luminous rays.

In *convex lenses* the *principal focus*, or the point where parallel rays meet, corresponds nearly to the centres of curvature of the lens. Convex lenses tend to *converge* all luminous rays passed through them.

The position of the image depends upon the distance away the object is from the lens.

a. If the object is at such a distance that the rays proceeding from it are parallel, the image will be *real, inverted, smaller* than the object, and situated at the centre of curvature of the lens.

b. If the object is beyond the centre of curvature, the image will be *real, inverted, smaller* than the object, and situated a little beyond the principal focus.

c. If the object is just beyond the centre of curvature, the image will be *real, inverted, larger* than the object, and situated some distance beyond the principal focus.

d. If the object is between the centre of curvature and the lens, the image will be *virtual, erect, larger* than the object, and situated beyond the principal focus.

Concave lenses. All rays passing through concave lenses tend to *diverge*; hence the image is always *erect, virtual*, and *smaller* than the object.

SPHERICAL ABERRATION IN LENSES.

When the lens is large, the rays which are transmitted near the edge reach a focus nearer the lens than those rays which pass through near the axis, consequently the image is indistinct, or there is *spherical aberration* by refraction.

CHAPTER XX.

DISPERSION AND ACHROMATION OF LIGHT.

When white light, or that which reaches us from the sun, passes from one medium into another, it is decomposed into several kinds of light. This decomposition is called *dispersion of light*.

Thus if a pencil of solar light pass through a prism, and be thrown upon a screen, seven principal colors are pictured there, which are, from above downward, violet, indigo, blue, green, yellow, orange, and red. These colors thus produced are called the *solar spectrum*. The violet is the most refrangible color, and the red the least.

The spectra formed by artificial light seldom contain all the colors of the solar spectrum, but those present are invariably in the same order as those composing that spectrum. The colors of the spectrum are *simple*—that is, they cannot be further decomposed. If, however, the various colors are recombined, the result is white light again.

The *color of bodies* depends upon the fact that one portion of the colored rays contained in white light is absorbed, while the other portion is reflected, giving them their color.

The bodies that reflect all the colors are white, while those that reflect none are black; *mixed colors* are those produced by a combination of two or more colors.

Complementary colors are those which, when combined,

produce white. *Homogeneous light* is light containing but one color, or *monochromatic light*.

Common salt burnt in Bunsen's lamp gives nearly a homogeneous light.

PROPERTIES OF THE SPECTRUM.

a. *Luminous properties.* Light in the yellow portion of the spectrum has the greatest, and in the violet the least intensity.

b. *Heating properties.* The hottest portion of the spectrum is just beyond the red, but depends somewhat upon the kind of prism used to effect the dispersion.

c. *Chemical properties* are more marked just beyond the blue portion of the spectrum.

DARK LINES IN THE SPECTRUM.

The color of the solar spectrum is not continuous, but for several grades of refrangibility rays are wanting, and, in consequence, it contains many dark lines. These lines are always in the same position.

In spectra of artificial lights and stars the positions of the dark lines are changed or replaced by bright ones, when compared with the solar spectrum.

Fraunhofer's lines is the name given to the most marked dark lines in the solar spectrum, and are designated by letters of the alphabet.

Incandescent vapors have the power, of absorbing rays of the same refrangibility as they ^{emit} ~~absorb~~, and it is this property of incandescent gases that explains the dark lines in the solar spectrum and leads us to believe that the sun is surrounded by incandescent gases which absorb the rays produced by the luminous properties of the same incandescent substance in the sun.

SPECTRUM ANALYSIS.

A very delicate means of detecting some of the ingredients in unknown substances is afforded by volatilizing a portion of the substance in a flame and denoting the color it imparts to certain of Fraunhofer's lines.

This method of examination is called *spectrum analysis*. It has been ascertained that whenever salts of the same metal are introduced into a flame they always produce lines identical in color and position.

Therefore by comparing the spectrum of any given substance with the solar spectrum, and noting which of Fraunhofer's lines are replaced by bright lines, a delicate means of analysis is afforded. *For example*, sodium always give a bright yellow line in the exact position of Fraunhofer's line D. with part of the spectrum absent.

The *spectroscope* is an instrument used for the study of the spectrum, and in its simplest form consists of two telescopes mounted on a common footing and a prism for forming the spectrum. One telescope collects the rays of light from the burning substance and throws them on the prism, while the other is used to magnify the spectrum produced. When three telescopes are used the spectra are formed by burning the substance to be examined in front of one of the telescopes by means of a Bunsen burner, which gives but little light of its own and thus does not obscure the lines in the spectrum to be produced, and some of the suspected substances in front of another.

The spectra thus formed are brought by means of a prism so they may both be seen by looking through the third telescope and a comparison made by noting the position of their bright lines. *For example*, if sodium is suspected of being present in a given substance, burn a

portion of it in a Bunsen flame in front of one of the telescopes, and a little sodium in front of the other, and if the bright lines of the two agree, the supposed substance is present. The spectroscope is also used in detecting certain fluids, as blood and bile.

This is done by placing some of the fluid between the source of light and the spectroscope. The spectrum thus produced has characteristic dark bands depending on the kind of fluid.

KINDS OF SPECTRA.

Continuous.

Discontinuous, or bright-lined.

Absorption, or dark-lined.

Positive, or bright-banded.

Negative, or dark-banded.

a. *Continuous spectra* are those formed by ignited fluids and solids.

b. *Discontinuous spectra* are those produced by ignited gases and elements.

c. *Absorption spectra* are those produced by the fixed stars and the sun.

d. *Positive or bright-banded spectra* are those produced by comets.

e. *Negative or dark-banded spectra* are those produced by blood, bile, chlorophyl, and other liquids.

FLUORESCENCE.

Fluorescence is that property some substances have of appearing colored when viewed by reflected light, but are colorless when seen by transmitted light.

This property is due to the retardation of the wave movement by the light being reflected and thus brought within compass of the eye.

Fluorescence is not limited to reflected light, but may also be produced by transmitted light, due to a change in the refrangibility of the rays by passing them through the substance. Thus placing a quinine solution in the solar spectrum the invisible ultra-violet rays become visible owing to a diminution in the refrangibility of these rays.

■CHROMATIC ABERRATION.

Simple lenses when a certain distance from the eye give colored images, due to the unequal refrangibility of the different colors, or *■chromatic aberration*. To correct this, *achromatic lenses*, or lenses preventing decomposition of light, are used, and made by combining lenses of different substances, such as crown and flint glass.

CHAPTER XXI.

OPTICAL INSTRUMENTS.

Among the most important optical instruments are the :

Microscope.

Telescope.

Magic-lantern.

Camera-obscura.

a. The *simple microscope* consists of a single convex lens of short focal length, the object being placed between the lens and its principal focus. As a result there is produced an *erect, magnified, and virtual* image. The *compound microscope* in its simplest form consists of two convex lenses. The one nearer the object is called the *object-glass* or *objective*, and has a short focus ; the other is called the *eye-piece* or *power*, and has a longer focus or is less condensing.

The object has to be placed very near the objective, just beyond its principal focus. This forms a *real, magnified, and inverted* image, which in turn is magnified by the eye-piece, as is the object in the simple microscope.

To bring more of the rays into the field of vision, a third convex lens, called the "Field lens," is sometimes employed and placed between the *objective* and its image, thus bringing the rays nearer together.

b. *Telescopes.* In *astronomical telescopes* there are object-glasses and eye-pieces. The object is beyond the principal focus of the objective, hence a *smaller, inverted, and*

real image is formed, which is magnified by the eye-piece, as in the compound microscope.

The *terrestrial telescope* differs from the astronomical in producing images in their proper positions. This is effected by means of two convex lenses placed between the objective and the eye-piece, so that the image when magnified by the eye-piece will appear erect.

In *Galileo's telescope*, on the principle of which *opera glasses* are constructed, the eye-piece consists of a double concave lens, which gives at once an erect image, and in this way differs from the astronomical telescope. The eye-piece is so placed that the image formed by the objective would fall behind it, if it were not that the rays in passing through the eye-piece are refracted and diverge, so that the eye which receives them sees the image *near by, magnified, and erect*.

c. *Magic-lantern*. This is an instrument for throwing magnified images upon a screen. The reflected rays of a lamp are made to fall upon a convex lens, which concentrates them upon the object to be magnified.

A double convex lens is then placed at a little more than the principal focal distance from the object, and consequently a *real, magnified, and inverted* image is produced on the screen.

d. *Camera-obscura*, consists of a dark chamber with a small aperture to admit the light.

The rays proceed from external objects through this opening, and form *small inverted* images of these objects on the opposite wall. The images are made much brighter and clearer by placing a double convex lens in the aperture. Photographs are taken by the camera.

CHAPTER XXII.

PHOTOGRAPHY.

Photography is the art of fixing images of the camera-obscura on substances sensitive to light.

The first real important step taken in photography was by *Daguerre* in 1839, and in honor to him the pictures thus taken are called *daguerreotypes*. A well-polished copper plate is made *sensitive* by exposing it to bromine and iodine vapors, which form iodide and bromide of silver. This plate is then placed in the camera at the point where the image will be formed, and allowed to remain a few minutes thus exposed to the rays of light.

The plate is next exposed to the action of mercurial vapor, which deposits metallic mercury only on the parts affected by the light. All other portions of the iodide and bromide of silver are removed from the plate by a solution of hyposulphite of soda, which does not affect the mercury. The plate is then washed with a solution of the chloride of gold, which combines with the mercury and increases the lustre of the picture.

Photographs are now taken on glass and then transferred to paper. The glass plate is first coated with collodion impregnated with iodide of potash. This plate is then immersed in a solution of nitrate of silver, thus forming on the plate iodide of silver, which is very sensitive to light. The plate is next exposed to the light in the camera, as in taking the *daguerreotypes*.

A *developer* or solution of protosulphate of iron is then poured over the plate, which reduces to the metallic state those parts of the iodide of silver acted upon by the light. The rest of the iodide of silver is washed off the sensitive plate with hypophosphite of soda.

The image thus produced is called the *negative*. The *positive* picture is obtained by impregnating paper with the chloride of silver, placing over it the negative, and exposing it then to the direct action of the sunlight for some time. That portion of the chloride of silver on the paper not acted upon by the light is then removed by a solution of hyposulphite of soda. The light portions of the negative are replaced by shades in the positive, thus making the pictures to a certain extent more natural—taking white, white; and black, black.

Gelatine plates are frequently used instead of glass; the process of taking the picture, however, is essentially the same.

I. Pictures produced by direct action of light :

1. Daguerreotype.
2. Talbotype—negative and positive prints.
3. Wax-paper process—Dr. Gray.
4. Albumen on glass.
5. Wet collodion process.

Ambrotypes.

Paper prints	{	Silver. Prussian blue. Platinum. Uranium. Gelatin.
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Glass positives.

6. Dry plates—Honey—Tannin.

7. Collodion emulsion.
8. Gelatine emulsion.

II. Photo-mechanical process :

1. Woodbury types.
2. Collotypes $\left\{ \begin{array}{l} \text{Albertypes.} \\ \text{Artotypes.} \\ \text{Heliotypes.} \\ \text{Indotints.} \end{array} \right.$
3. Gelatine transfers $\left\{ \begin{array}{l} \text{Photo-lithographs.} \\ \text{Photo-electrotypes.} \end{array} \right.$
4. Relief process $\left\{ \begin{array}{l} \text{Photo-electrotypes.} \\ \text{Photo-engravings.} \end{array} \right.$
5. Intaglio process $\left\{ \begin{array}{l} \text{Photo-etching.} \\ \text{Photo-electrotypes.} \end{array} \right.$

CHAPTER XXIII.

DOUBLE REFRACTION.

Some crystals, as Iceland spar, have the property of splitting up the ray of light which passes through them into two parts, so that when any object is seen through one of these crystals it appears double.

This property is explained by assuming that ether in *double refracting* bodies is not equally elastic in all directions, so that the vibrations at right angles to each other are transmitted with unequal velocities. One of the rays into which the incident ray is divided is called the *ordinary*, as it represents the ordinarily refracted ray; and the other the *extraordinary* ray, as it differs from commonly transmitted light.

The images formed by double refraction are called the *ordinary* and *extraordinary*, from the rays that produce them.

The ordinary rays and images correspond to those of single refraction.

INTERFERENCE OF LIGHT.

When two luminous rays from different sources meet at acute angles, the mutual action produced is called *interference of light*, and as a result well-marked colors and bands are formed which depend wholly upon the meeting of these rays.

Interference of light or *diffraction* takes place when

light traverses the edge of a body, or through a small aperture. It is also produced when light is reflected from finely striated surfaces, as the *mother of pearl*, or from thin transparent laminæ, as glass, ice, soap bubbles, etc. *Newton's rings* are examples of interference of light, and can be seen by either transmitted or reflected light. They are produced by a thin layer of air interposed between two glasses tightly compressed.

This phenomenon produced by the interference of light is due to the meeting of the waves of luminiferous ether, and, coming from different sources, either weaken or strengthen each other. As the waves of luminiferous ether have different lengths and velocities for each color, this interference of two rays consequently causes a different display of colors than would have been produced by either.

The red rays have the longest and the violet the shortest wave-lengths.

POLARIZATION OF LIGHT.

Light, besides undergoing double refraction, is sometimes *polarized*—that is, made to vibrate in one plane only.

Thus if a ray of light which has undergone *ordinary* refraction be allowed to pass through a second crystal, it may be divided into *ordinary* and *extraordinary* rays with unequal intensities, so that rotating the second crystal will cause one ray to disappear entirely and the other to be increased in brightness. The same is true with the ray which has undergone *extraordinary* refraction, if made to pass through the second crystal.

When light is polarized, the ordinary and extraordinary rays are polarized in planes at right angles to each other.

MEANS OF POLARIZING LIGHT.

Light may be polarized by:

Reflection.

Single refraction.

Double refraction.

a. *By reflection.* The instrument used for polarizing light by reflection is called a *polariscope*. It consists of a hollow tube with a plate of dark glass at each end, so arranged as to be able to revolve about each other, and to assume any angle. If light strike the first reflecting surface at an angle of $35^{\circ} 25'$, called the *polarizing angle*, the reflected light becomes polarized—that is, vibrates in one plane only. If the surface of the second glass is parallel to that of the first, the polarized ray will be reflected, but if at right angles to it no light will be reflected. All reflected surfaces have a *polarizing angle*—that for water being $52^{\circ} 45'$.

b. *By single refraction.* When a luminous ray falls upon a glass plate at the polarizing angle, part of it is reflected and part refracted. That which is refracted is found to be partially polarized also, and if made to pass through several such plates placed parallel, the refracted ray will be found completely polarized.

c. *Double refraction.* By this means of polarizing light, two prisms are needed. One is called an *analyzer*, for by means of rotating it the ordinary and extraordinary rays are made to appear and disappear, thus indicating that the light is polarized; and the other the *polarizer*, by means of which the light is polarized.

The best prisms used for polarization are made of *tourmaline*, which has the property of absorbing the *ordinary* ray, and Iceland spar, which also, as in *Nicol's prism*, has the property of transmitting only one beam of the polarized light.

INTERFERENCE OF POLARIZED LIGHT.

When rays of polarized light meet, they cause *interference*, as do the rays of ordinary refracted light, and as a result are produced fringes of light with various colors, these colors depending upon the planes of polarization.

This phenomenon is best produced by transmitting the polarized ray through lamina of double refracting crystals, compressed glass, etc. By rotating these crystals beautiful colored rings are produced.

ROTATORY POWER OF LIQUIDS.

A great many liquids, as saccharine solutions, possess the power of rotating the plane of polarized light either toward the right or the left, and by noting the direction and the number of degrees this plane is rotated from its original position, the composition of different substances may be detected when chemical analysis fails.

This rotatory polarization is determined by passing the polarized light through the liquid when the analyzer is so placed that no light is transmitted. The polarized beam will now pass through the analyzer, and by turning it to the right or left until no light is transmitted, will give the number of degrees of the liquid's rotatory power.

Soleil's saccharimeter is an apparatus, the principle of which is based on the rotatory power of saccharine solutions.

By noting the number of degrees any given saccharine solution causes the plane of polarized light to rotate, the amount of sugar can be approximately obtained.

CHAPTER XXIV.

SOURCES OF LIGHT.

Light is furnished us by :

- a. Heavenly bodies.
- b. Chemical combustion.
- c. Electricity.
- d. Phosphorescence.

Phosphorescent substances are those that after exposure to certain conditions will shine in the dark. This phenomenon may be referred to the following causes :

- a. Spontaneous phosphorescence, or that seen in vegetables and animals.
- b. Elevation of temperature.
- c. Mechanical effect.
- d. Electricity.
- e. Exposure to the sun's rays.

The sulphate of calcium and strontium are two such substances, and will shine in the dark for many hours after exposure to strong light.

ELECTRICITY AND MAGNETISM.

CHAPTER XXV.

MAGNETISM.

Magnets are bodies that attract iron, and the force exerted is called *magnetism*.

Theory of magnetism :

In all bodies, two magnetic fluids, called *positive* and *negative*, are circulating in opposite directions among the molecules. In most substances these fluids neutralize each other, but in magnets the *positive* fluid collects at one end of each molecule and the *negative* at the other end.

KINDS OF MAGNETS.

Magnets are either :

Natural.

Artificial.

a. A *natural magnet*, or *loadstone*, is an oxide of iron— Fe_3O_4 .

b. *Artificial magnets* may be :

1. Temporary.

2. Permanent.

Temporary magnets are made of iron, which assumes the property of magnets by passing an electric current around the iron (*see chapter on electro-magnets*), or by magnetic induction.

After the exciting cause is removed the iron loses its magnetic properties.

Permanent magnets are made of steel, which assumes the magnetic property by passing a strong current of electricity around the steel, or by rubbing the steel with a magnet for some time.

After the exciting cause is removed the steel retains its magnetism.

PROPERTIES OF MAGNETS.

Magnets have the following properties :

Attracting iron.

Assuming a given direction.

Declination.

Inclination, or dip.

Magnetic induction.

Magnetic rupture.

a. The *attracting force* of a magnet is more marked the nearer the ends are approached, and diminishes toward the centre, at which point it is absent.

The *poles* of a magnet are near the ends, where the attracting force is the greatest.

The *neutral point* is at the centre of the magnet, where the attracting power is nothing.

b. A *magnet* or *magnetic needle*, when freely suspended, assumes a given direction, with its poles always pointing in the same direction. The pole pointing toward the north is called the *north pole*, while the one toward the south is called the *south pole*.

Poles of the same name repel each other, while those of opposite name attract each other.

An *astatic needle* is one not influenced by the earth's magnetism, and is usually a combination of two needles, with poles in contrary directions.

c. *Declination* of magnetic needle. The north and south poles do not point geographically north and south. The amount of declination, however, is not constant, but differs in places and from time to time.

d. *Inclination* or *dip* of the magnetic needle is its tendency, when freely suspended, to incline from the horizontal plane. North of the equator the north pole dips as the geographical pole is approached, until, before that point is reached, the needle becomes vertical in direction.

The same is true of the south pole south of the equator. Those points where the needle assumes the perpendicular are called the *magnetic poles* of the earth.

e. *Magnetic induction* is that property which magnets have of temporarily making magnets of iron when brought directly or nearly in contact with the iron. Such a temporary magnet has in turn, but to a lesser extent, power of induction on other iron.

As soon as the influence of the permanent magnet is taken away, the iron loses its magnetic properties.

f. *Rupture of magnets*. When a magnet is broken into a number of pieces, every portion will become immediately a complete magnet in itself.

CHAPTER XXVI.

ELECTRICITY.

Electricity is a physical agent manifesting itself by attraction, repulsion, heat, light, etc.; not inherent in bodies, but evoked by a variety of causes, as friction, chemical action; and the electrical condition of such a body is called *potential*.

Theories :

1. *Franklin's theory.* All substances contain an imponderable fluid in a quiet state, but when excited, as by friction, a portion of this fluid is drawn off, leaving a preponderance of the other portion, which causes the phenomena of electricity.

2. *Timmer's theory.* All substances contain two fluids which ordinarily neutralize each other, but when excited are separated and cause the manifestations of electricity.

Admitting this fluid theory of electricity, any body may be charged with an excess of either one fluid or the other, which are called *positive* and *negative* fluids, and from which we have the following law: *Two bodies charged with the same electricities repel each other, but with opposite electricities attract each other.*

CONDUCTORS AND NON-CONDUCTORS.

Bodies in which electricity passes rapidly from one part to another are called *good conductors*; but those bodies in which it does not, are called *poor conductors* or *non-conductors*. Glass is the best non-conductor. *Poor conductors* are also called *insulators*.

CHAPTER XXVII.

KINDS OF ELECTRICITY.

There are two principal kinds of electricity :

1. Statical.
2. Dynamical.

STATICAL ELECTRICITY.

Statical or frictional electricity was the first kind of electricity discovered, and is produced by friction.

PROPERTIES OF STATICAL ELECTRICITY.

Statical electricity has the properties of :

Surface distribution.

Rapid dissipation.

Induction.

a. The *distribution* of electricity in any body charged with statical electricity, is upon the surface, and has the greatest intensity at the most acute points on that surface.

b. Statical electricity is rapidly *dissipated* from bodies even when they are properly insulated—that is, mounted on non-conductors.

Electricity is dissipated by :

The air.

Imperfect insulation.

c. There is *induction by statical electricity* as there is induction by magnets. Thus, when an insulated con-

ductor is charged with electricity, any body in a neutral state and insulated, placed near it, will be acted upon in a manner analogous to that of a magnet upon soft iron.

In other words, it decomposes the neutral fluid in the body, attracting the opposite and repelling the like kind of electricity. This body will in turn have a similar action on other insulated bodies, but all will have their electric fluids neutralized again by withdrawing the influence of the charged conductor.

The different kinds of electric fluid—*negative* and *positive*—are collected at the extremities of these bodies charged with induced electricity, while at the centre is a space destitute of free electricity.

CHAPTER XXVIII.

ELECTRICAL MACHINES.

Among the most important of statical electrical machines are the :

Electroscope.

Glass plate machines.

Electrophorus.

Leyden jar.

a. The *electroscope* is an instrument used for detecting the presence and kind of electricity in a body.

This consists essentially of an insulated metallic rod at the end of which two gold leaves are attached.

If any electrified body is brought near the rod, the electric fluid will be decomposed by induction, and consequently the gold leaves will be charged with one kind of electricity, causing them to diverge, while the opposite end of the rod will be charged with the other kind.

The *presence* of electricity is thus determined by the divergence of the gold leaves, but not the *kind*. This is determined as follows: While the rod is still charged by induction from an electrified body, touch the end of the rod. This will remove one kind of electricity and leave the rod charged with the opposite or other kind. After removing the finger take away the ⁱⁿreducing agent and apply to the rod a *positively electrified* body, as an excited brass rod.

If the gold leaves diverge more widely the former body

was *negatively* charged, for like electricity will be repelled to the opposite extremity. The reverse is true if the gold leaves are less divergent.

b. *Plate electrical machines* are instruments used principally for storing up statical electricity. The usual form of this machine consists of a circular plate of glass at the upper and lower parts of which are two cushions which act as rubbers when the plate is turned. In front of the plate are two insulated conductors terminating in branches which are bent around the plate between the rubbers and studded with points projecting toward the glass. When the plate is turned or revolved it becomes charged with *positive electricity* by friction against the rubbers. To equalize this *positive* electricity on the glass plate, *negative* electricity is given off from the conductors through the projecting points, thus leaving the conductors charged with positive electricity.

The cushions are connected with the earth by a metallic chain so that the negative electricity from the plate can escape to the ground. *Holtz* invented a machine by which a body is electrified by friction once for all, and made to act by induction in such a way as to produce a continual generation of electricity by the rotation of a glass plate. The electrophorus acts on the same principle.

c. The *electrophorus* consists of a disc of resin and a metallic disc with an insulated handle. The resin is electrified by friction and the metallic plate then placed upon it, which in turn becomes charged with electricity by induction from the resin. If this plate still in position is touched by the finger, the like kind of electricity passes to the ground, while the plate remains charged with the opposite kind. If now removed from the resinous disc by means of the insulated handle, it still contains but one kind of

electricity, and by touching it a spark denotes the union or the neutralizing of the two fluids.

This can be repeated a number of times without again exciting electricity in the resin.

CONDENSATION OF ELECTRICITY.

A *condenser* is an apparatus for storing up a large quantity of electricity on a small surface.

There are a great many forms of condensers, but the *Leyden jar* is the most convenient.

d. The *Leyden jar* consists of a glass bottle, the interior of which is coated with tin-foil, and the exterior of the neck of the bottle with the same material. The neck of the bottle is provided with a cork through which passes a brass rod terminating externally in a knob and internally by a chain communicating with the tin-foil.

The jar is charged by connecting the external surface with the ground and the interior, by means of the brass knob with the source of electricity. In this way the inner surface of the jar becomes charged with one kind of electricity and the outer by the opposite kind, owing to the law of attraction and repulsion of electrical fluids.

By connecting the outer with the inner coatings of the jar, by means of a good conductor, the two fluids unite, or the jar is discharged, as indicated by a spark.

It is found by experiment that nearly all the charge of electricity resides on the inner and outer surfaces of the glass and not on the tin-foil, the mutual attraction of the two opposite electricities causing them to approach as nearly as possible, their union being prevented by the poor conductivity of the glass.

The extent of charge for a Leyden jar depends directly upon the extent of surface and inversely upon the thickness of the insulator—glass.

CHAPTER XXIX.

EFFECTS OF ELECTRICAL DISCHARGE.

The electric discharge is the phenomenon which accompanies the union of two opposite electric fluids, and may be either *continuous* or *sudden*, the difference being one of degree and not of kind.

The effects of the discharge may be either :

Physiological.

Luminous.

Heating.

Magnetic.

Mechanical.

Chemical.

a. The *physiological effects* consist in a violent exciting action on the sensible and contracting elements of the organic tissues through which electricity passes.

b. *Luminous effects* often accompany the recombination of the two electrical fluids, and manifested by flashes or sparks of light, the color depending upon the surrounding medium. Its spectrum is full of dark lines.

c. *Heating effects*. The electric spark is the source of intense heat. Gas can be ignited, alcohol set on fire, etc., by the spark coming in contact with it.

d. *Magnetic effects*. By passing the discharge through a coil of wire inside of which a steel needle is placed, the needle will afterwards be found magnetic.

e. *Mechanical effects* consist in lacerations, fractures, etc.,

which follow a powerful discharge of electricity through a poor conductor.

Lightning rods are placed on buildings to allow of the harmless passage of electricity from the clouds to the ground. They are best made of gas-pipe filled with pulverized charcoal; the tips made of solid iron. The rods should extend in the ground below moisture, and should be connected both above and below ground.

f. *Chemical effects* result in decomposition and recombinations, produced by the passage of the electrical discharge through substances.

Thus gases in proper proportions are made to combine, by passing a spark through them.

CHAPTER XXX.

DYNAMICAL ELECTRICITY.

The discovery of *dynamical or current* electricity is due to *Galvani*, whose investigations on the influence of electricity on animals, especially the frog, led to additional discoveries as to the nature of this form of electricity.

Volta attributed the contractions of the frog's legs in Galvani's experiments to the metal conductor used to excite these contractions, so he constructed the *Voltaic pile*, which consists of a series of discs of copper, zinc, and wet cloth arranged in uniform order.

This experiment worked so well that it led to further investigations, which resulted—as the general belief that this form of electricity was due to chemical action—in the construction of *chemical batteries* for the production of electricity.

ELECTRICAL UNITS.

Before considering the construction of electric batteries it is important to understand the units of measurement used in electricity.

These are the :

Coulomb.

Ampère.

Volt.

Ohm.

Watt.

a. A *coulumb* or *weber* is the quantity of electricity that passes in one second under a force of one *volt* and against one *ohm*.

b. An *ampère* is the current produced by one *volt* against one *ohm*, and will decompose .00142 of a grain of water.

c. A *volt* is the force necessary to produce a current of one *ampère* against one *ohm*. It about equals the force produced by one *Daniell cell* (see kind of batteries).

d. An *ohm* is the resistance to the current electricity necessary to allow of one *ampère* under a force of one *volt*. It is equivalent to the resistance offered by a telegraph wire $\frac{1}{20}$ " diameter and 250 feet in length.

e. A *watt* is the power developed by one *ampère* falling one *volt*, and is equal to $\frac{1}{720}$ of a horse-power.

CHAPTER XXXI.

CHEMICAL BATTERIES.

In all batteries the metal acted upon is called the *positive* and the other the *negative* plate.

If these two plates are connected with a wire the *direction* of the current is determined by the *positive* metal—that is, the current always passes *from* the *positive* to the *negative* in the fluid, and from the *negative* toward the *positive* out of the fluid.

By the *direction* of the current is always meant the direction of the *positive* current, or the one above described. The *negative* current always takes the opposite direction, but for all practical purposes it is never considered.

If the wire connecting the two plates be divided, the electricity collects at the divided ends, hence these are called the *poles* or *electrodes*.

The *positive electrode* is always the one connected with the *negative* plate, while the *negative electrode* is connected with the *positive* plate.

KINDS OF BATTERIES.

Among the many batteries constructed the following are the most important :

The simple battery.

Daniell's battery.

Grove's battery.

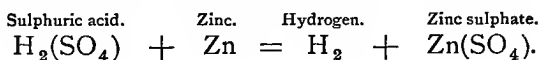
Bunsen's battery.

Gravity battery.

Grenet battery.

Leclanche battery.

a. The *simple battery* consists of a plate of copper and one of zinc suspended in a weak solution of sulphuric acid. The chemical action which results, causing the production of electricity, is as follows:



The *zinc* is the *positive* and the *copper* the *negative* plate.

This form of battery is seldom used, for the current rapidly diminishes until after a few hours it ceases to act at all.

This diminution is due to the following causes:

1. Decrease of chemical action.

2. Local action.

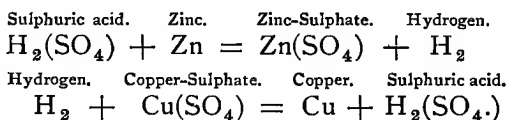
3. Polarization of negative plate. *Local action* is the production of small closed circuits of electricity in the positive plate, due to impurities.

This can be prevented to a certain extent by *amalgamating* the zinc—that is, rubbing it over with metallic mercury.

Polarization is the formation of hydrogen gas on the copper plate, thus interfering with the contact between the fluid and the metal. The hydrogen also decomposes the zinc-sulphate, causing a deposit of metallic zinc on the copper.

b. *Daniell's battery*. This consists of a glass vessel filled with a solution of sulphate of copper, in which is immersed a cylinder of copper and crystals of the sulphate of copper.

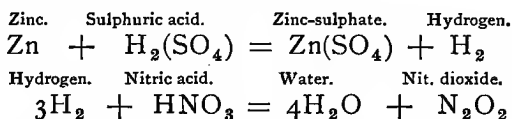
Inside the cylinder is a porous earthen cup containing a weak solution of sulphuric acid, suspended in which is a cylinder of zinc. The chemical action resulting is as follows :



In this way the hydrogen decomposes the sulphate of copper, thus preventing the polarizing of the copper plate, and the sulphuric acid formed replenishes that which is decomposed by its action on the zinc. The sulphate of copper which is decomposed by the action of the hydrogen is replenished by the undissolved crystals.

c. *Grove's battery*. This consists of a glass vessel filled with diluted sulphuric acid, immersed in which is a cylinder of zinc.

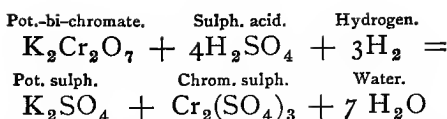
Within this cylinder is a porous earthen cup containing nitric acid, suspended in which is a plate of platinum. The following chemical action results :



The N_2O_2 fumes pass off in the air.

d. *Bunsen's battery* is the same as *Grove's*, except the platinum is replaced by a carbon plate, the chemical action being the same.

e. *The chromic acid or Grenet batteries* are like *Bunsen's* and *Grove's*, except the nitric acid is replaced by a solution of bi-chromate of potash in sulphuric acid, thus doing away with the disagreeable fumes.



f. The *gravity battery* consists of a glass vessel in the bottom of which is a copper plate covered with crystals of sulphate of copper. The vessel is then filled with water and a zinc cylinder immersed in it. The chemical action is the same as seen in *Daniell's battery*.

The sulphate of zinc which forms floats on the surface of the sulphate of copper, owing to its lower specific gravity, and the battery thus replenishes itself.

g. *Leclanche battery* consists of a carbon rod in a porous cup containing a mixture of gas, graphite, and peroxide of manganese; surrounding this porous cup is a zinc plate immersed in a strong solution of sal-ammoniac which is the exciting fluid. The electro-motor force is great, but as the battery soon becomes polarized it is not adapted to continuous work, but if left to itself will soon regain its strength.

In all these forms of batteries, a single cell is called an *element*, but a combination of cells a *battery*.

In combining the cells, the positive plate in one is connected with the negative in another by means of a wire, and so on from one element to another, until all the cells are joined. Increase the number of elements and in this way increase the *strength* of the current.

If on the contrary all the same kind of plates in the elements are joined together, we increase the surface acted upon, and in this way the *quantity* of electricity produced is proportionally increased.

Change the size of the elements and the *quantity* of electricity is altered, but not its intensity.

CHAPTER XXXII.

ATTACHMENTS TO A BATTERY.

The most important attachments to a battery are the—
Galvanometer.

Rheostat.

Current selector.

Communicator.

Rheophores.

Electrodes.

a. The *Galvanometer* is an apparatus by means of which the direction and intensity of currents can be determined, and is based upon the principles of deflection of the needle by the current.

The *direction* and *measurement* of voltaic currents of electricity are determined by the magnetic effects they produce.

If a wire is suspended horizontally in the direction of a magnet, and a current be passed through this wire, the needle is deflected and tends to take a position which is more nearly at right angles to the magnetic meridian in proportion as the current is stronger.

If, however, instead of having a single wire, a complete circuit is formed around the needle, or several such circuits are made, the effect is multiplied.

If the observer imagine himself the wire, the current entering his feet and passing out of his head, and his face always toward the needle, the north pole of the needle will always be deflected toward the left of the current.

b. The *rheostat* is an appliance used to regulate the external resistance of a current. It is made of various substances, but the fluid rheostat is the best. It is so arranged that the external current is made to pass through various amounts of fluid, the amount interposed regulating the strength of the current.

c. The *current selector* is an apparatus so arranged that any given number of cells composing the battery can be thrown in or excluded from the circuit. It is usually arranged in form of a switch on a key-board.

d. The *communicator* is an apparatus for changing the poles of a battery without disturbing the *rheophores* and is also usually arranged as a switch upon a key-board.

e. The *rheophores* are the wires transmitting the current from the battery to the *electrodes*, and are usually made of copper wire insulated with silk or cotton covering.

f. The *electrodes* are the termini of the rheophores, and are made of various substances, as sponge, metal, wires, etc.

The negative electrode is called the *katrode*, and the positive the *anode*.

CHAPTER XXXIII.

INTENSITY AND RESISTANCE OF THE ELECTRO-MOTOR FORCE.

The *electro-motor force* is that force by which electricity is set in motion. It is the difference in potential of the cell elements and is therefore unchanged by their size.

The difficulty which a current has in completing its circuit is called the *resistance*, and may be either external or internal.

a. *External resistance* is that offered to the passage of the current between the *negative* and *positive* elements of the cell, and is modified by the *length*, the *diameter*, and *character* of the conductor employed.

b. The *internal or fluid resistance* is that offered to the passage of the current between the *positive* and *negative* elements of the cell, and may be modified by the *distance between*, the *character of the fluid between*, the *intervention of some foreign body between*, and by the *size* of, the elements. The larger the elements, the more direct the passage of the current, the better the conducting power of the fluid, and the nearer the elements the less will be the internal resistance.

The intensity and resistance of the electro-motor force are governed by the following laws:

a. *Ohm's law*: *The intensity of a current is equal to the electro-motor force, divided by the resistance ; and is inversely*

proportional to the length, and directly to the section, of the conductor.

b. *The resistance of current is inversely proportional to the intensity of the current and section of the conductor, and directly as the length of the conductor.*

CHAPTER XXXIV.

EFFECTS OF CURRENT ELECTRICITY.

The effects of current electricity may be :

Magnetic.

Heating.

Luminous.

Physiological.

Chemical.

a. The *magnetic effects* have already been considered.

b. *Heating effects.* The heat disengaged in any given time is directly proportional to the square of the strength of the current and to the resistance.

A battery of thirty Bunsen elements will melt copper wire, hence the thermal effect of the current is used for firing mines, cauterizing, etc.

The heating effects depend more upon the size of the plates than upon the number of them when the resistance is not great.

c. *Luminous effects.* In making and breaking a voltaic current at the point of contact a spark is obtained. If at the two terminals of a strong battery, pencils of carbon are placed near together, and an intense current passed, the pencils become incandescent, and a luminous arc extends between the two points called the *voltaic arc*.

The electric light has the same chemical properties as solar light. Its spectrum has several bright lines.

In the *incandescent-electric lamps*, of which Edison's and Maxum's are good examples, the luminous effects are produced by the intense heating of a carbon thread or platinum wire by passing an electric current through them in a vacuum or a rarefied atmosphere of nitrogen or gaseous hydrocarbons containing no oxygen. As it takes a current of from 40 to 50 Bunsen elements to produce an electric light equal to 500 candle power, it is found advisable to obtain the required amount of electricity by means of the magneto-electric machine.

d. *Physiological effects.* The voltaic current has the property of causing contraction of all protoplasmatic matter, and excitement throughout the nervous system. These effects are only produced at the opening and closing of the circuit.

e. *Chemical effects.* Many substances are decomposed into their elements by the voltaic current. This decomposition is called *electrolysis*. This positive electrodes effecting the electrolysis is called the anode, and the negative the kathode.

Many substances previously considered elements have by *electrolysis* been proven to be of a compound nature. In the decomposition of salts the acids are liberated at the *anode*, and the bases at the *kathode*. Electrolysis cannot take place in substances unless they are conductors.

ELECTRO-METALLURGY.

Electro-metallurgy or *galvanoplastics*, is the decomposition of salts by which certain metals are precipitated on the negative plate. In this way electro-gilding is done.

A mould of the object to be reproduced by electroplating is first taken, and if not a good conductor is made so by coating with graphite. It is then suspended in a solution of the metal to be deposited and connected

with the negative pole of the battery, while a plate of a similar metal is suspended in the fluid, and connected with the positive pole. The electric current decomposes the fluid and deposits the metal on the mould (negative plate).

CHAPTER XXXV.

ELECTRO-DYNAMICS.

Electro-dynamics treats of the laws of electricity in a state of motion, or the action of electric currents on each other and on magnets. *Two currents parallel, and in the same direction, attract each other, but in contrary directions, repel each other.*

Currents impart the same rotatory motion to magnets that they do to currents, directing them at right angles to the current; but not only do currents act upon magnets, but magnets also act upon currents, causing them to rotate when the magnet is fixed.

The earth, which exercises a directive action on magnets, acts also on currents. Thus every vertical current tends to place itself under the earth's influence, in a plane perpendicular to the earth's magnetic meridian, but every horizontal current tends to have a continuous rotatory movement rather than a directive one.

Not only has the earth a directive tendency on a freely movable current, but also causes, as in the magnet, an inclination or dip of a circuit when it is properly balanced.

MAGNETIZATION BY CURRENTS.

Electro-magnets are bars of soft iron which under the influence of a voltaic current become magnets. But this magnetism is only temporary, for so soon as the current ceases the iron is no longer a magnet, or if at all, a very

weak one, the magnetism remaining being called *residual*. These electro-magnets are usually made in the horse-shoe form, and the insulated copper wire is wound around the two armatures in the same direction, so as to form bobbins.

As a general rule *electro-magnetic force or strength is directly proportional to the strength of the current, and to the number of windings of the wire, but independent of the nature and thickness of the wire.*

It is on the principle of the electro-magnet that all telegraphing is done.

CHAPTER XXXVI.

VOLTAIC INDUCTION.

Induction by the voltaic current is the action which currents or magnets exert on conductors.

Currents thus produced are called *induction* or *faradic* currents.

Induction can be produced by :

Magnets.

Interrupted currents.

Continuous currents.

A current upon itself.

a. If a *magnet* be introduced into the centre of a hollow coil of insulated wire, at the moment of introduction and withdrawal a momentary current will be excited in the coil of wire. These excited currents are opposite in direction.

b. Induction by *interrupted* currents can be produced by introducing an insulated coil of wire, called *primary*, into another insulated coil, called the *secondary*, and passing a current of electricity through the primary.

At the moment of making and breaking this current, a *secondary current* will be excited in the *secondary coil*, but in opposite directions, viz. : at the moment of *making* in the *inverse* direction to that in the *primary coil*, and in the *same* direction at the time of *breaking*.

c. By *continuous currents*. When a primary coil is traversed by a continuous current and brought near a

secondary coil, or is removed from it, currents are excited in this secondary coil as were produced by the interrupted currents.

d. Induction can be excited by a *current on itself* when two portions of the same insulated wire are placed side by side, the sudden making and breaking of a current in one wire will excite a current in the other, called *extra*. The making of this current is a hindrance to the passage of electricity throughout the length of the wire, for the *extra current* is an inverse one, but the breaking intensifies the current, as it is in the same direction as the current itself.

By placing a core of soft iron in the interior of any of the coils above mentioned for the production of induced currents, the effect will be intensified, the iron acting as a magnet when the current is transmitted around it.

The following law governs induced currents: *The strength of the induced currents is proportional to the inducing currents and to the products of the lengths of the inducing and induced currents.*

APPARATUS FOUNDED ON INDUCTION.

The following apparatus is founded on induction:

Magneto-electrical machines.

Induction coils.

Faradic battery.

Telephone.

a. The *magneto-electrical machine* in its simplest form consists of a horse-shoe magnet around which two bobbins are made to revolve. The wire forming these bobbins is coiled on two cylinders of soft iron jointed by plates of iron or brass, thus forming *electro-magnets*. So that the induced currents produced may be in the same

direction, the wire on the bobbins is coiled in opposite directions. By each complete revolution of the electro-magnet, its two armatures become alternately magnetized in contrary directions, and in each wire an induced current is produced, the direction of which changes at each half turn. By aid of a *communicator* the currents may all be made to pass in the same direction.

The difference between a *dynamo* and a magneto-electric machine is that in the former we have electro-magnets and in the latter permanent ones.

In the large magneto-electric machines like those now used for electric lighting, electro-gilding, electrolysis, etc., as many as 64 such bobbins are used and made to revolve around the poles of horse-shoe magnets. About 235 revolutions per second produce the greatest degree of light.

For the electric light it makes no difference if the currents are produced in opposite directions, but for other purposes the current must be made to pass in the same direction by means of the communicator.

b. *Induction coils*, of which *Rhumkorff's* is a good example, are arrangements for producing induced currents of electricity by means of electric currents whose circuits are opened and closed alternately in rapid succession.

These coils consist essentially of hollow cylinders, primary and secondary, in which are placed bundles of iron wire. The primary coil is connected with the poles of a battery, the current of which is alternately opened and closed by a self-acting arrangement called an *interrupter*, while the other serves for the development of the induced current.

By means of an apparatus of this kind, currents of electricity are produced superior in effects to those obtained by *electrical machines* or *Leyden batteries*. In *Rhumkorff's*

machine there is placed in the bottom a *condenser* made of tin-foil so insulated that each alternate layer, forming one coating, is connected with the inducing current, thus storing up some of the electricity from the battery and *extra currents*, while the remaining layers, forming a second coating, are connected with the secondary or induced currents, thus increasing their strength by using this stored-up electricity.

c. In the *faradic battery* the current from a galvanic cell is made to pass through a coil of insulated wire called the *helix*, which surrounds a bundle of soft iron wire to be magnetized. When the wires are magnetized by the current it draws the *interrupter* toward it, thus breaking the circuit and demagnetizing the wires. The interrupter returning to its place reconnects the circuit, and the same steps are repeated. As the current is an alternating one the polarity changes with each interruption. The primary helix is usually surrounded by a secondary one, which has no connection with the battery cell, but receives its current by induction from the primary coil, and is of very high tension.

This secondary current is modified in strength by a sliding tube of metal which passes between the two coils, thus regulating the amount of induction.

The *rheophores* are connected at will with either the primary or secondary coils, and thus made to transmit either the primary or secondary currents.

d. The *telephone* is an instrument whose action depends upon the fact that whenever the relative positions of a magnet and a closed coil of wire are altered there is produced within the coil a current of electricity. The magnet and the coil in the telephone remain fixed, but the iron membrane or diaphragm in the mouthpiece, which vi-

brates backward and forward when spoken into, becomes magnetized by induction from the magnet. These vibrations give rise to currents in the coil surrounding the permanent magnet, which are transmitted through the circuit to the distant coil surrounding its magnet, which in turn alternately attracts and ceases to attract the corresponding diaphragm, thus producing similar sounds by exciting vibrations in the air.

In *Bell's telephone* an electro-magnet is used instead of the permanent magnet in the closed coil of wire.

The diaphragm vibrating before this electro-magnet produces induced currents in the circuit, which are transmitted to the corresponding electro-magnet in the receiver, producing like vibrations in that diaphragm.

In *Edison's telephone* a plate of carbon is interposed in the circuit, and the diaphragm is made to vibrate against that, thus alternately increasing and diminishing the pressure on the carbon. It has been found that the carbon under different pressure transmits the electric current with different intensities, producing the same result as adding induced currents to the circuit, and therefore causing like vibrations in the diaphragm of the receiver.

The *microphone* is an apparatus working on the same principle as the Edison telephone. Compression of the carbon diminishes the resistance of an electric current, while a diminution of the commission greatly increases it. The carbons of this instrument are so arranged that the waves of sound are communicated to them, altering their electric conduction so that very weak sounds are plainly heard in an attached telephone receiver.

CHAPTER XXXVII.

THERMO-ELECTRIC CURRENTS.

Currents of electricity can be produced by applying heat or cold to one of the junctions of a circuit composed of different metals.

The electricity thus produced is called *thermo-electric currents*.

In the *thermo-electric pile* a large number of elements or metals are used in a small space, and alternately soldered together.

The elements may be of many kinds, or, better still, many elements of the same kind.

PART II.
THEORETICAL CHEMISTRY.

THEORETICAL CHEMISTRY.

Chemistry treats of the atomic composition of matter, and of those changes in matter which result from a rearrangement of these atoms.

Matter is any thing we can appreciate by our senses, and is made up of *sixty-six elements*, or substances that cannot be divided into other substances.

Matter may be divided into :

Atoms.

Molecules.

Masses.

Atoms are the smallest divisions of matter, and unite to form molecules.

A *molecule* is the smallest group of atoms, that will exhibit the physical and chemical properties of the substance, and cannot be divided without losing these characteristics.

A *mass* is a collection of molecules.

COMPOSITION OF MOLECULES.

The composition of a molecule is ascertained by :

a. *Analysis*, which consists in separating the molecule into its constituent atoms ; and

b. *Synthesis*, which consists in uniting the constituent atoms to form the molecule.

The atoms thus composing any molecule may be alike, forming *elemental* molecules ; or unlike, forming *compound*

molecules. Rearrangement of the atoms in any elemental molecule yields no new kind of matter, as does the rearrangement of atoms in compound molecules.

There have been found but sixty-six such elemental molecules or substances, and these have received the name of *elements*.

From these sixty-six kinds of atoms, all masses of matter are made up.

These elements are all named, and each name has, for convenience, received a symbol. They are as follows:

TABLE OF ELEMENTARY BODIES, WITH THEIR SYMBOLS
AND ATOMIC WEIGHTS.

TABLE I.

NAME.	SYMBOL.	ATOMIC WEIGHT.
Aluminum,	Al	27.4
Antimony,	Sb	120
Arsenic,	As	75
Barium,	Ba	137
Bismuth,	Bi	206.5
Boron,	B	11
Bromine,	Br.	80
Cadmium,	Cd	112
Cæsium,	Cs	133
Calcium,	Ca	40
Carbon,	C	12
Cerium,	Ce	141
Chlorine,	Cl	35.5
Chromium,	Cr	52.4
Cobalt,	Co	58.8
Copper,	Cu	63.4
Didymium,	D	144.78
Erbium,	E	165.9
Fluorine,	F	19

NAME.	SYMBOL.	ATOMIC WEIGHT.
Fluorine,	F	19
Gallium,	Ga	68.8
Glucinum,	Gl	9
Gold,	Au	197
Hydrogen,	H	1
Indium,	In	113.4
Iodine,	I	127
Iridium,	Ir	192
Iron,	Fe	56
Lanthanium,	La	138.5
Lead,	Pb	207
Lithium,	Li	7
Magnesium,	Mg	24
Manganese,	Mn	54
Mercury,	Hg	200
Molybdenum,	Mo	96
Nickel,	Ni	58.8
Niobium,	Nb	94
Nitrogen,	N	14
Osmium,	Os	199.2
Oxygen,	O	16
Palladium,	Pd	105.7
Phosphorus,	P	31
Platinum,	Pt	194.4
Potassium,	K	39.1
Rhodium,	Rh	104.4
Rubidium,	Rb	85.4
Ruthenium,	Ru	104.4
Scandium,	Sc	44
Selenium,	Se	78.8
Silicum,	Si	28
Silver,	Ag	108
Sodium,	Na	23
Strontium,	Sr	87.6

NAME.	SYMBOL.	ATOMIC WEIGHT.
Sulphur,	S	32
Tantalum,	Ta	182
Tellurium,	Te	128
Thallium,	Tl	204
Thorium,	Th	233
Tin,	Sn	118
Titanium,	Ti	50
Tungsten,	W	184
Uranium,	U	238
Vanadium,	V	51.2
Ytterbium,	Yb	172.7
Yttrium,	Y	89.8
Zinc,	Zn	65.2
Zirconium,	Zr	89.6

NUMBER OF ATOMS IN ELEMENTAL MOLECULES.

From the law of Ampère : *Equal volumes of all bodies in the gaseous state contain the same number of molecules*, it follows, *that the molecules of all bodies when in the gaseous state are of the same size ; and their weight compared to that of hydrogen is proportional to the weight of any given volume, compared with the same volume of hydrogen. For example, if one volume of hydrogen gas contains one hundred molecules, then an equal volume of chlorine will contain one hundred molecules.*

If these volumes be mixed together and exposed to the sunlight, they will unite and form two volumes of hydrochloric-acid gas, containing two hundred molecules.

The *atomicity* of any molecule is the number of atoms which it contains. Most of the elements contain *two* atoms to the molecule, but mercury, cadmium, zinc, and barium contain *one* ; ozone, *three* ; phosphorus and arsenic, *four* ; and sulphur, *six*.

ATOMIC AND MOLECULAR WEIGHTS.

The *atomic weight* of any atom is its relative weight compared to hydrogen, which is taken as unity (1).

The *molecular weight* of any molecule is the sum of the atomic weights of its constituents.

Thus the molecular weights of chlorate of potash, KClO_3 , would be :

	Atomic weight.
K	39.1
Cl	35.5
$\text{O}_3 (16 \times 3)$	48.
	<hr/> 122.6

By dividing the atomic weight of any of these constituent elements into the molecular weight of the compound, the proportion by weight of each element is determined. Thus in chlorate of potash (KClO_3), one third of it by weight is oxygen. The atomic weight of oxygen is 16, but as there are three atoms, their combined atomic weight would be 48 (16×3). The molecular weight of the compound is 122.6; therefore the weight of the oxygen would be $\frac{48}{122.6}$, or over one third.

ATOMIC EQUIVALENCE.

The *equivalence* of any atom is the quantity of its combining power expressed in hydrogen units, which has a combining power of 1.

These atoms having the combining power of one (1) are called *monads*; of two (2), *diads*; of three (3), *triads*, etc. Many atoms have more than one combining power—that is, they may have an equivalence of 1, 3, 5, etc., or 2, 4, 6, etc., but this combining power in the same kind of atoms always increases or diminishes by two.

Atoms whose equivalence is even are called *artiads*; those whose equivalence is odd, *perissads*. The following table gives the most constant equivalence of elements:

TABLE II.

MONADS.	DIADS.
Hydrogen.	Strontium.
Fluorine.	Barium.
Chlorine, i, iii, v, vii.	Magnesium.
Bromine, i, iii, v, vii.	Zinc.
Iodine, i, iii, v, vii.	Cadmium.
Lithium.	Cerium.
Potassium.	Mercury (Hg_2) ⁱⁱ
Silver.	Copper (Cu_2) ⁱⁱ
TRIADS.	Oxygen.
Antimony, iii, v.	Sulphur, ii, iv, vi.
Bismuth, iii, v.	Calcium.
Boron.	TETRAIDS.
Gold, i, iii.	Carbon.
Nitrogen, i, iii, v, vii.	Silicon.
Phosphorus, i, iii, v.	Tin, ii, iv.
Arsenic, iii, v.	Aluminum (Al_2) ^{vi}
HEXADS.	Platinum, ii, iv.
Chromium, ii, iv, vi.	Lead, ii, iv.
Manganese, ii, iv, vi.	
Iron, ii, vi, (Fe_2) ^{vi}	
Cobalt ii, (Co_2) ^{vi} .	
Nickel, ii, (Ni_2) ^{vi} .	

For example. Hydrogen is a monad and chlorine is a monad; consequently one atom of hydrogen will just saturate one atom of chlorine. Again, hydrogen being a monad and oxygen a diad, it will take two atoms of hydrogen to saturate one of oxygen, etc.

Iron, Cobalt, Nickel, Mercury, Copper, and Aluminum, frequently unite with other elements by the use of *two* atoms as well as one. The equivalence of these elements when combining with the use of double atoms is given in the above Table II.

Thus one atom of mercury (Hg), which is a diad, will combine with two of chlorine, which is a monad, or two atoms of mercury (Hg_2), will combine with two of chlorine, thus making entirely different compounds (Hg Cl_2) and ($\text{Hg}_2 \text{Cl}_2$).

The *graphic symbol* of any atom is one indicated by a circle with lines radiating from it equal in number to its combining power. Thus an atom of hydrogen would be indicated by a circle with one radiating line—oxygen with two lines, etc.

MULTIPLICATION OF ATOMS AND MOLECULES.

Atoms are multiplied by placing a numeral below and to the right of its symbol. Thus C indicates one atom of carbon; C_2 , two atoms of carbon, etc.

Molecules are multiplied in the same way, after inclosing their symbols in brackets, or by placing the numerals before the molecular formula. Thus, $(\text{H}_2\text{O})_2$ or $2\text{H}_2\text{O}$ would represent two molecules of water; $(\text{H}_2\text{O})_3$ or $3\text{H}_2\text{O}$, three molecules of water, etc.

When the number of atoms of any constituent in a molecule is more than one, this is indicated by a numeral placed below and to the right of its symbol. Thus CO_2 would represent one molecule of carbon dioxide.

NEGATIVE AND POSITIVE ATOMS.

In considering the formation of acids, bases, and salts, the atoms constituting them are either positive or negative.

A *positive atom* is one which is attracted to the negative pole in electrolysis.

A *negative atom* is one which is attracted to the positive pole in electrolysis.

Hydrogen and the metallic or basic elements are usually positive, while oxygen, nitrogen, chlorine, and the other so-called acid elements are negative.

CHEMICAL FORMULAS.

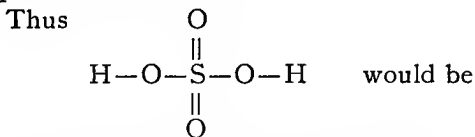
A *compound molecule* is one whose constituent atoms are unlike.

The representation of any compound molecule by symbols is called a *formula*. Thus, HCl is hydrochloric acid; H₂O, water, etc.

Formulas may be empirical, rational, graphic, or typical.

An *empirical* formula is one derived from analysis, and is merely an expression of the kind and relative number of atoms in any molecule. Thus, H₂SO₄ would be the empirical formula for sulphuric acid.

A *graphic* formula expresses the kind and absolute number of atoms, together with the arrangement and equivalence of each.



the graphic formula for sulphuric acid.

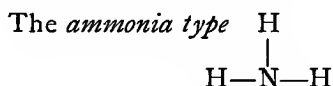
A *rational* formula is one giving the kind and number of atoms, split up into groups, showing of what it is composed and into what elements or molecules it may be decomposed by means of reagents.

Thus, H₂O, SO₃ is a rational formula of sulphuric acid

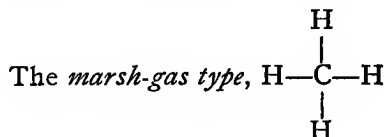
The *type* formula is one built up on the plan or structure of some well-known chemical compound. The *water-type* formula H-O-H is the most common. By replacing one or more H's with negative or positive atoms, bodies are said to be formed upon the water type. Thus K-O-H is the water-type formula for potassium hydrate.

Besides the water type of compounds there are several other types, the most important being the *hydrochloric-acid-type*, the *ammonia type*, and the *marsh-gas type*.

In the *hydrochloric-acid type*, H-Cl , by the replacing of the hydrogen atom by other atoms, as sodium, potassium, etc., a new class of compounds is formed, as sodium and potassium chloride, etc.



is also an important type, especially in the formation of organic compounds. These compounds are formed by replacing one or more of the hydrogens by other atoms. Thus by replacing one hydrogen there remains (NH_2) , called *amodogen*, which, acting as a monad radical, can unite with the monad potassium, forming $(\text{NH}_2) \text{K}$, or with the diad calcium, by taking two molecules of the radical, forming $(\text{NH}_2)_2 \text{Ca}$.



is also an important type in organic chemistry. New compounds are formed by substituting other atoms in the place of one or more hydrogens.

NAMING MOLECULES.

Binary molecules are those containing two atoms directly united, as Na-Cl.

Ternary molecules are those whose dissimilar atoms are united by a third atom, as K-O-H.

The names of all compound molecules are derived from those of their constituents.

When the constituent atoms of binary molecules have but one equivalence, as sodium and chlorine, the termination *ide* is generally added to the negative element. Thus, NaCl is sodium *chloride*. Magnesium and oxygen each have an equivalence of two, hence MgO is magnesium *oxide*, etc.

In cases, however, where the constituent atoms have more than one equivalence, as, for example, nitrogen, which has an equivalence of 3 and 5 usually, then the compound with the lower equivalence takes the termination *ous*, and the higher one *ic*. Thus nitrogen, a triad, uniting with oxygen, a diad, the result is *nitrous oxide*. Again, nitrogen, a pentad, uniting with oxygen, a diad, the result is *nitric oxide*.

Compound molecules having a lower equivalence still than the *ous*, the prefix *hypo* is attached; or if higher than the *ic*, the prefix *per*. Thus, theoretically, nitrogen may be a monad or a septad, and if united to oxygen, a diad, there would be formed *hypo-nitrous oxide* and *per-nitric oxide*.

In a few cases the number of atoms combining to form the molecule is indicated in naming the substance. Thus, CO₂ is called carbon di-oxide, because there are two atoms of oxygen, which distinguishes it from CO, carbon mon-oxide.

The term *sesqui*, when prefixed to a binary molecule,

indicates that the atoms bear a relation to each other of 3 to 2. Thus Fe_2O_3 is sesquioxide of iron.

Sub prefixed to a chemical compound means *lower* or *lesser*, and is frequently used synonymously with *ous*.

CONSTRUCTION OF MOLECULES.

When atoms with different equivalents unite to form compounds, each atom must furnish the same number of bonds, this number being the least common multiple of their atomic equivalence; and the number of atoms required by each constituent is obtained by dividing the least common multiple by the equivalence of each atom.

Thus, if nitrogen is a triad and oxygen a diad, both must furnish six bonds ($2 \times 3 = 6$), the least common multiple of 2 and 3. To furnish these bonds, nitrogen, which already has three bonds, must furnish two atoms ($6 \div 3 = 2$), while oxygen, having but two bonds, must furnish three atoms ($6 \div 2 = 3$).

The formula formed by this union of nitrogen and oxygen must be N_2O_3 , $\text{N}=\text{O}$



SATURATED AND UNSATURATED MOLECULES.

When the bonds of all the atoms constituting a molecule are mutually combined, the molecule is called *saturated*; but when some of the bonds remain free, the molecule is *unsaturated*, and the group of atoms composing it form a *compound radical*.

When the unsaturated atoms are all of the same kind, the group is called a *simple radical*.

As radicals cannot exist in a free state in nature, they enter into combination with other atoms as do single

atoms, and take the termination *yl*. Thus, in water (H_2O), if one hydrogen is removed there remains HO, a compound radical called *hydroxyl*.

As hydrogen is a monad and oxygen a diad, HO has one free bond which may unite with any atom having one free bond, as potassium, forming KOH, or with other radicals having one free bond, as NO, thus forming HNO_2 .

In some cases artiad radicals, or compound radicals with an even number of free bonds, can exist free in nature by mutual saturation of these free bonds. Thus CO, carbonal or carbon-mon-oxide is a diad radical, carbon having four bonds, only two of which are saturated by oxygen, but as the remaining bonds saturate each other ($< \text{C} = \text{O}$) it may exist free in nature.

In perissad radicals, however, this can never take place, for there always exists an odd number of free bonds, consequently the union of any one free bond with another would still leave the molecule unsaturated.

It is by this mutual saturation of bonds that a triad may become a monad, or a tetrad a diad, etc.

THE FORMATION OF ACIDS, BASES, AND SALTS.

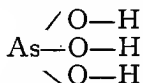
An *acid molecule* is one consisting of one or more negative atoms united by oxygen to hydrogen, (Cl-O-H) and has the property of turning vegetable blues—as litmus-red.

It is sometimes called a salt of hydrogen.

Acids are formed from the oxides of negative elements by the addition of a molecule of water.

Thus Cl_2O is an oxide of chlorine; add water ($\text{Cl}_2\text{O} + \text{H}_2\text{O} = 2 \text{HClO}$) and an acid of chlorine (HClO) is formed.

Ortho acids. Primary acids, or those in which all the oxygen has a linking function, are called ortho, and the number of oxygen and hydrogen atoms must be equal. For example: arsenious acid, H_3AsO_3 , is an ortho acid, for all the H's are linked to As by O. Thus:



Meta acids. Meta acids are derived from the ortho by taking from them one or more molecules of water, thus forming mono-, di-, or tri-meta acids. For example: H_3AsO_3 is an ortho-arsenious acid; taking away H_2O we have HAsO_2 , a meta arsenious acid.

Pyro acids mean those having reverted or changed their chemical formula by means of heat. $\text{H}_4\text{P}_2\text{O}_7$ is pyrophosphoric acid.

A *basic molecule* is one consisting of one or more positive atoms united by oxygen to hydrogen.

Thus, sodium hydrate (NaOH) is a base. Sodium is a positive atom united by oxygen to hydrogen, $\text{Na}-\text{O}-\text{H}$.

Many chemists define a base as a metallic oxide, and a basic element as a metallic element.

A *saline molecule* is one consisting of one or more positive atoms united by oxygen to one or more negative atoms.

Thus NaOCl is a salt of sodium. Sodium is a positive atom united by oxygen to ~~nitrogen~~, a negative atom, $\text{Na}-\text{O}-\text{Cl}$.

These acids, bases, and salts are formed on the plan of the structure of water ($\text{H}-\text{O}-\text{H}$), commonly called the *water type*. Thus exchanging for one of the hydrogens a negative atom an acid is formed, for a positive atom a base; and by exchanging both hydrogens, one for a negative and the other for a positive atom, a salt is produced.

Chemically speaking, a salt is usually produced by the action of an acid upon a base, or, theoretically, by replacing one or more of the hydrogens of any acid by basic elements.

There are three kinds of salts, called acid, normal, and double. An *acid salt* is one in which all the hydrogens of the acid have not been replaced by basic elements, as disodium phosphate (Na_2HPO_4).

An acid salt sometimes takes the prefix of *super* or *bi* as in *super-phosphates* or *bi-carbonates*.

A *normal salt* is one in which all the hydrogens have been replaced, as sodium phosphate (Na_3PO_4).

A *double salt* is one in which the acid hydrogens are replaced by more than one kind of basic elements, as ammonio-magnesium phosphate (NH_4), MgPO_4 .

NAMING ACIDS AND SALTS.

As compound molecules take the terminations *ous* and *ic* and the prefixes, *hypo* and *per*, according to the number of equivalence of their constituent atoms, so when acids are formed by the union of hydrogen by oxygen to these compound molecules, they also take like terminations.

Thus hyponitrous oxide united to hydrogen by oxygen forms hyponitrous acid. In the same way is formed nitrous acid and nitric acid.

In a like manner any salt produced by the action of an *ous* acid forms an *ite* salt, while an *ic* acid forms an *ate* salt either with or without the prefixes *hypo* and *per*. Thus we have by the action of nitrous acid on sodium hydrate the formation of sodium nitrite, while the action of nitric acid on the same base forms sodium nitrate.

CHEMICAL REACTIONS.

All molecules are subject to chemical change, and any change taking place among the atoms constituting any molecule is called *chemical reaction*.

This change is expressed by molecular formulæ, the chemical reactions being represented in the form of equations. Thus let AB be one molecule of any substance to be acted upon by another molecule CD, then the equation would be expressed thus: $AB + CD = AD + CB$. As no loss of weight can be the result of any chemical change, then the molecular weight of the two sides of the equation must be equal, and also the number of atoms.

If the chemical change results in the production of any substance insoluble in the menstruum employed, such a compound will appear as a precipitate. If, on the contrary, a volatile substance is produced by such a chemical change, it will be evolved as a gas or vapor.

PART III.
INORGANIC CHEMISTRY.

INORGANIC CHEMISTRY

CHAPTER I.

Inorganic chemistry treats of all the elements, both metallic and non-metallic, in their free and combined states as they occur in the inorganic world.

The chemistry of plants and animals is treated of under organic chemistry, or chemistry of the carbon compounds.

In the consideration of each element, the following order of arrangement will assist the student in memorizing the facts in their most important relations :

I. The name of the element, its symbol, atomic weight, and equivalence.

II. Its history.

III. Its occurrence.

IV. Its preparation.

V. Its properties.

a. Physical.

b. Chemical.

VI. Its uses.

VII. Its compounds.

HYDROGEN.

Symbol H. *Atomic weight* 1. *Equivalence* 1.

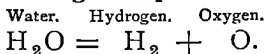
History. Hydrogen was discovered in 1766 by Cavendish, who described it under the name of inflammable air.

Occurrence. Hydrogen exists free in certain volcanic gases, in or around the sun and some of the fixed stars.

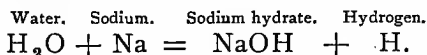
In the combined state it is found in water, in all animal and vegetable tissues, petroleum, etc.

Preparation :

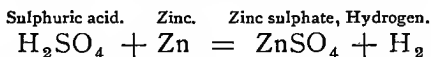
1. Water (H_2O), by means of electrolysis, will separate into its constituent atoms, oxygen collecting at the positive and hydrogen at the negative pole. Thus:



2. If metallic sodium is thrown upon water, the water is decomposed, and hydrogen is set free. Thus:



3. By the action of sulphuric acid upon metallic zinc, the sulphuric acid is decomposed and hydrogen set free. Thus:



4. By passing heated steam over anthracite coal. Thus:



This when passed over naphtha to keep it together becomes *water gas*. $\text{CO}_2 + 2\text{H}_2 + \text{C} \rightleftharpoons 2\text{CO} + 2\text{H}_2$

Properties :

a. *Physical.* Hydrogen is a colorless, odorless, and tasteless gas. It is the lightest form of matter known, hence its diffusibility is greater than any other gas. It is but slightly soluble in water.

b. *Chemical.* Hydrogen is combustible—that is, at an elevated temperature it will combine with oxygen with the evolution of light and heat. It will not support combustion. It burns with a pale blue flame, and with an intense heat. Its product of combustion is water.

Uses. Hydrogen on account of its lightness is used to inflate balloons. It is used also as a heating agent on account of its high temperature produced by combustion.

CHAPTER II.

OXYGEN.

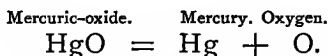
Symbol O. *Atomic weight* 16. *Equivalence* 11.

History. Oxygen was first discovered by Priestley in 1774, and described by him as dephlogisticated air. Scheele discovered it independently the next year, and called it empirical air.

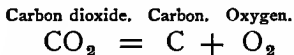
Occurrence. Oxygen is the most abundant element in nature. It forms one fifth part of the atmosphere, where it exists free. In the combined state it forms two thirds of the globe—water being two thirds and minerals one half oxygen by weight. It is found combined with other elements in all animal and vegetable tissues.

Preparation :

1. Mercuric oxide exposed to a high temperature is decomposed and metallic mercury and oxygen are produced. Thus :



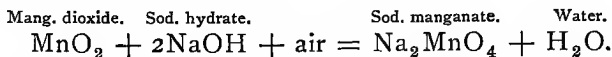
2. Carbon dioxide (CO₂) in the leaves of plants is decomposed by the sunlight into carbon and oxygen. Thus :



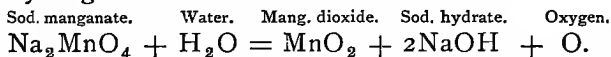
3. By electrolysis of water described under the chapter on hydrogen.

4. It is prepared from the oxygen of the air in the following manner :

1. Pure air is passed over a heated mixture of manganese dioxide (MnO_2) and sodium hydrate (NaOH), thus forming sodium manganate (Na_2MnO_4) and water H_2O . Thus:

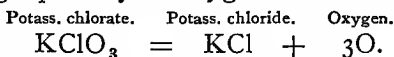


2. This heated sodium manganate (Na_2MnO_4) is then raised to a high temperature, and a current of steam passed over it, which decomposes it into its original constituents again, and setting oxygen free from its mixture with hydrogen. Thus:



This process can be kept up continually, and oxygen manufactured in large quantities.

5. The usual method of preparing oxygen for commerce is by heating chlorate of potash (KClO_3), which yields a large quantity of oxygen. Thus:



Properties :

a. *Physical.* Oxygen is a colorless, odorless, and tasteless gas. It is a little heavier than air and but slightly soluble in water.

b. *Chemical.* Oxygen enters into combination with all the elements except fluorine.

The combination of any element with oxygen really constitutes combustion, but the term is usually restricted to those combinations of oxygen which are accompanied with heat and light, the usual result if the oxidation is a rapid one.

As the result of oxidation, oxides are produced.

Uses. Oxygen is used for aiding combustion for purposes of either heat or light.

In the air, diluted with nitrogen, its uses for respiratory purposes are well known.

COMPOUNDS OF OXYGEN AND HYDROGEN.
HYDROGEN OXIDE OR WATER.

Formula, H_2O or $\text{H}-\text{O}-\text{H}$.

History. Water was considered an elementary substance until Lavoisier, in 1773, proved its compound nature.

Occurrence. Water occurs abundantly in nature, both free and combined. Occurring in the free state it is either :

Atmospheric or
Terrestrial.

I. Atmospheric water occurs in the form of rain, snow, hail, mist, etc.

II. Terrestrial waters are :

Sweet,
Salt
Mineral.

a. *Sweet* water is found in :

1. Springs.
2. Rivers.
3. Lakes.
4. Wells.

b. *Salt* water is found in :

1. Oceans.
2. Inland seas.

c. *Mineral* waters are those that contain an excess of mineral ingredients, and are named from their principal constituents. Thus :

1. Saline, containing chlorides and sulphates.
2. Alkaline, containing bicarbonates.

3. Chalybeate, containing ferrous bicarbonates.
4. Acid—containing free acids, usually sulphuric.
5. Alum, containing alum or potash alum.
6. Acidulous, containing carbonic acid.
7. Sulphur, containing sulphites, H_2S , and sulphides.
8. Borax, containing borax.
9. Silicious, containing sodium silicate.

Saratoga waters are alkaline and contain large quantities of common salt $NaCl$.

Water in the combined state presents four degrees of combinations, as:

- a. Hygroscopic moisture, or that which can be driven off at a temperature of $212^{\circ} F$.
- b. Water of crystallization.
- c. Chemical combination, also called hydration.
- d. Solvent. Not always a mere mechanical solution, for heat or cold is often the result.

Ingredients of water. Natural waters are seldom pure—that is, they contain more than the constituent elements, hydrogen and oxygen.

Water always contains a certain amount of mineral matter, such as potassium, sodium, calcium, and magnesium in the form of chlorides, bicarbonates, and sulphates. Besides this mineral matter, it also contains organic matter derived from the decomposition of plants, and gases in solution derived from the air.

Preparation. Water is always the product of combustion in presence of oxygen. It can be prepared by direct union of its constituents mixed in proper proportion by means of an electric spark. It is also the result of many chemical combinations.

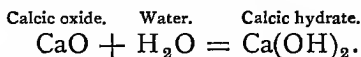
Properties :

- a. *Physical.* Water is a colorless, odorless, and taste-

less liquid. A poor conductor of heat and electricity. It is taken as the standard for the specific gravity of liquids. Its maximum density is at 4°C ., it expanding for all lower and higher temperatures. It freezes at 0°C ., forming a crystalline solid—ice; and is converted into vapor or steam at 100°C .

Most gases are soluble in water; it dissolves them in proportion to their *volume* and not their density.

b. *Chemically*, water is very active, entering into chemical combination with many substances. Thus :

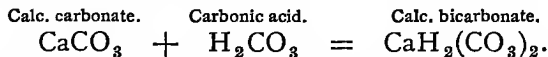


Efflorescent substances are those that lose their water of crystallization and become powdered.

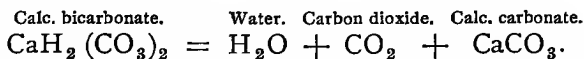
Deliquescent substances are those that attract moisture and liquefy.

Uses. Water is used for manufacturing and domestic purposes, and may contain ingredients which make it unfit for either.

The ingredients present which render the water harmful for *manufacturing* purposes are the minerals, especially the calcium salts, which are deposited in the boilers as calcium carbonate (CaCO_3). This salt is not soluble in pure water, but is soluble in water containing carbonic acid (H_2CO_3). Thus :



This salt is soluble in water, but upon the application of heat it is decomposed into carbonic dioxide and calcium carbonate. Thus :



This calcium carbonate depositing on the inside of boilers

destroys them. An apparatus called the calcium catcher is sometimes attached to boilers to remedy this danger. Saw-dust and other foreign substances are sometimes put in the boilers for the calcium to deposit upon instead of upon their iron plates.

Slacked lime and alum (1 gr. to gallon) will, when added to water, precipitate the lime salts which will not form incrustations, and are therefore frequently used for that purpose.

In water for *domestic* use the presence of mineral matter does no harm unless the water contains much calcium, which renders it "hard," and hence poor for washing and cooking purposes.

It is here, however, that the organic matter present may or may not prove very harmful to health. If the organic matter present in the water be due to the decomposition of vegetable matter, and it is not great in amount, it will do no harm.

If, on the contrary, the organic matter is the result of animal impurities, sewage, etc., in which disease germs are often present, it may be the means of causing much sickness. Boiling the water will destroy these impurities, but freezing will not.

The presence of much chlorine, ammonia, or nitrites in the water renders it suspicious—chlorine, for it indicates sewage contamination; ammonia, organic matter; and nitrites, animal decomposition.

Tests:

a. For *chlorine*. Add to the water a little nitric acid (HNO_3) and then nitrate of silver (AgNO_3). The chlorine is precipitated in white flakes, as the chloride of silver.

b. For *organic matter*. Add permanganate of potash

to the water; if much organic matter is present it will oxidize the potash solution and thus destroy its color.

c. For *ammonia*. Add to the water a little "Nessler reagent"—a solution of iodide of mercury (HgI_2) and caustic potash (KOH),—and if ammonia is present it will turn the water a dark yellow color; the more the ammonia, the darker the solution.

To make a complete analysis of drinking-water, find the amount of:

1. Total solids.
2. Volatile organic matter.
3. Chlorine.
4. Sodium chloride.
5. Free ammonia.
6. Nitrates.
7. Nitrites.
8. Albuminoid ammonia.
9. Hardness.

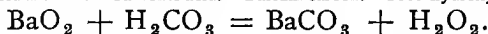
The water should also be examined microscopically, for by this means bacteria, micro-organisms, and various organic substances are discovered, and, if found suspicious by their presence, "*cultures*" may be produced by adding a drop of the water to sterilized gelatine.

HYDROGEN DIOXIDE OR FREE HYDROXYL.

Formula. H_2O_2 . $\text{H}-\text{O}-\text{O}-\text{H}$.

Preparation. It is always the result of slow oxidation, and is prepared by the action of carbonic or hydrochloric acid (H_2CO_3 or HCl) upon barium oxide. Allowing the water present to evaporate slowly, leaves the H_2O_2 behind as a syrupy liquid. Thus:

Barium oxide. Carbonic acid. Barium carbon. Free hydroxyl.



Properties. Hydrogen dioxide is a colorless, syrupy liquid, which decomposes at temperatures over 100° into water and oxygen. As it evolves oxygen readily, it is an oxidizing agent.

Uses. It is used in bleaching vegetable colors and as an antiseptic.

OZONE.

Symbol O_3 . *Molecular weight*, 48.

Ozone is not an element but a form of oxygen with three instead of two atoms to a molecule, and sometimes described as active oxygen.

History. Although ozone was really discovered in the eighteenth century, Schonbein, in 1840, was the first to describe it.

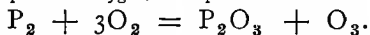
Occurrence. Ozone is found free in the air, especially after a thunder-shower. It is probably produced also in the atmosphere by the growth of plants.

Preparation :

1. Electricity. By its passage through the air, as by lightning, or by the electrolysis of water acidulated with hydrochloric acid (HCl), ozone is formed.

2. Ozone is prepared by the slow oxidation of phosphorus or sulphur. Thus:

Phosphorus. Oxygen. Phosphoric oxide. Ozone.



or by the rapid oxidation of red-hot platinum.

Properties :

a. *Physical.* Ozone is a colorless gas with an odor like that of weak chlorine. It is a little heavier than oxygen.

b. *Chemically* it is a more active oxidizer than oxygen. It bleaches strongly and is poisonous to animal life, although easily converted into oxygen. It decomposes potassium iodide (KI), setting free iodine vapor, which

colors starch solution blue. This acts as a test for the presence of ozone.

Uses. Ozone is a powerful bleaching agent, and as it readily oxidizes it is used by many as a disinfectant for water-closets, etc., to destroy foul odors.

CHAPTER III.

NITROGEN.

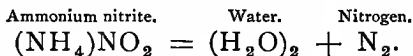
Symbol N. *Atomic weight* 14. *Equivalence* I-III-V.

History. Nitrogen was discovered by Rutherford, in 1772, in the air which had been breathed by animals.

Occurrence. Nitrogen is found free in the atmosphere. In the combined state it is found in the ammonia compounds, nitrates and nitrites, and in many of the animal and vegetable tissues.

Preparation. The easiest way to obtain nitrogen is from the air, where it exists in a free state. This is accomplished by using the accompanying oxygen by combustion—in other words, by burning out the oxygen.

Chemically it is prepared by heating ammonium nitrite (NH_4NO_2), thus breaking it up into water and nitrogen. Thus :



Properties:

a. *Physical.* Nitrogen is a colorless, odorless, and tasteless gas. It is lighter than air and soluble in water.

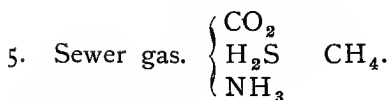
b. *Chemical.* Nitrogen is very inert, entering directly into combination with very few elements. In combination, however, it is very active, forming corrosive and explosive mixtures as nitric acid, nitro-glycerine, etc. It will not support combustion.

Uses. One of the principal uses for nitrogen is a natural one in diluting the oxygen of the air so as to render it suitable for respiratory purposes, and for limiting its oxidizing properties.

THE ATMOSPHERE.

Composition. The atmosphere is made up of a mixture of normal and abnormal ingredients. These are :

I. <i>Normal.</i>	PARTS PER 100.
1. Oxygen,	20.50
2. Nitrogen,	78.00
3. Watery vapor,	1.40
4. Carbon dioxide,	.05
5. Ozone,	trace
6. Gaseous hydrocarbons,	trace
7. Hydrogen sulphide,	trace
8. Ammonia,	trace
9. Acids,	trace
Total,	100.00
II. <i>Abnormal.</i>	
A. Dead matter.	
a. Mineral.	
1. Sand.	
2. Clay.	
3. Cosmical dust.	
4. Sodium chloride	} from sea water.
5. Calcium sulphate	
b. Non-mineral.	
1. Animal substances.	
2. Vegetable substances.	
3. Excrements.	
4. Products of decomposition.	



B. Live matter.

1. Pollen of plants.
2. Germs. $\begin{cases} \text{Disease germs.} \\ \text{Fungi.} \\ \text{Yeast plant.} \end{cases}$

Ground air is that found in the earth down to the level of the water. It is apt to be very unwholesome, as it takes up microbes from the sewers and bad water which percolates through the ground. This air readily gains access to houses through the cellars unless they are properly cemented.

Properties:

a. *Physical.* Air is one of the standards used for the specific gravity of gases. It exerts a pressure of 15 lbs. to the square inch on the surface of the earth. The height of the atmosphere is not known, but probably exists for fifty miles above the earth, its density diminishing as it ascends.

b. *Chemical.* It is a mixture of oxygen and nitrogen, and not a chemical union. The gases do not separate on account of the law governing their diffusion.

The atmosphere is a good supporter of combustion and a poor conductor of heat and electricity. It is slightly soluble in water.

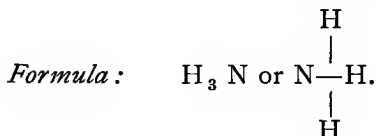
Uses. The most important use of the atmosphere is for respiratory purposes.

The most deleterious ingredient in the air is the disease germs. These are especially found in sewer gas and are conveyed to the air mechanically from sewage by bubbles.

Compounds

I. OF NITROGEN AND HYDROGEN.

HYDROGEN NITRIDE, OR AMMONIA.

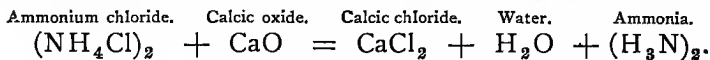


History. Ammonia has been known for many centuries, but the name was not given it until 1781 by Bregman.

Occurrence. It occurs but sparingly in nature, a little being found in water, air, soil, and animal matter.

Preparation. The compounds of ammonia are usually prepared by the destructive distillation of animal matter, or from the ammoniacal liquor obtained from distillation of coal.

Ammonia gas is best prepared by the action of quicklime (CaO) upon ammonium chloride (NH_4Cl). Thus:

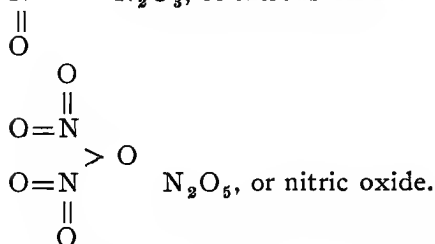
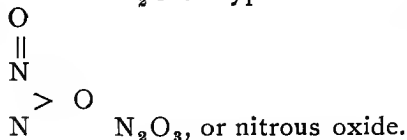
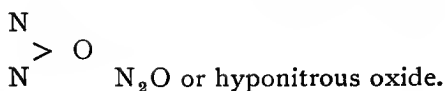


a. *Physical.* Ammonia is a colorless, pungent, and alkaline gas, turning red litmus paper blue. It is very volatile, lighter than air, and freely soluble in water. Will not saponify fats.

b. *Chemically,* it will not support combustion, and is slightly combustible at elevated temperatures. It is readily decomposed by heat and electricity into nitrogen and water.

2. OF NITROGEN AND OXYGEN.

As nitrogen has an equivalence of I., III., and V., we have by combination with oxygen several oxides of nitrogen. Thus:



From these oxides, acids are formed on the plan of the water type by substituting for an atom of oxygen in each of the oxides two hydroxyls (OH); or by adding a molecule of water to each. Thus:



$\text{N-O-H}, (\text{HNO})_2 = \text{N}_2\text{O} + \text{H}_2\text{O}, (\text{HNO})_2$, or hyponitrous acid.

$\text{N}_2\text{O}_3 + \text{H}_2\text{O} = (\text{HNO}_2)_2$, or nitrous acid.

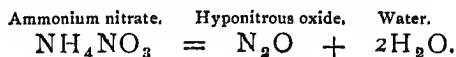
$\text{N}_2\text{O}_5 + \text{H}_2\text{O} = (\text{HNO}_3)_2$, or nitric acid.

The salts of these acids are formed theoretically by replacing the hydrogen by basic elements.

HYPONITROUS OXIDE.

Formula: N_2O .

Preparation. Hyponitrous oxide is prepared by heating ammonium nitrate (NH_4NO_3), which decomposes into hyponitrous oxide and water. Thus:



Properties:

a. *Physical.* It is a colorless, odorless gas with a sweetish taste. It is commonly called "laughing-gas," or nitrous oxide. When inhaled it produces insensibility. It is heavier than air and soluble in water.

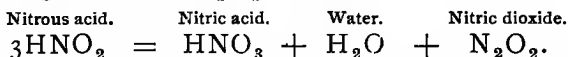
b. *Chemical.* It supports and accelerates combustion by being decomposed by heat and its oxygen set free.

Uses. As an anæsthetic.

NITROUS ACID.

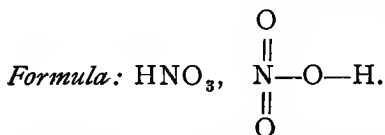


Properties. Nitrous acid is a very unstable compound. It is a bluish liquid, and has to be kept at a low temperature or it will decompose into nitric acid (HNO_3), water, and nitrogen dioxide N_2O_2 . Thus:

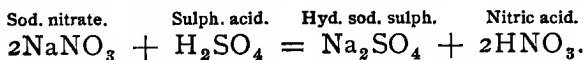


The salts formed from the union of nitrous acid and a base are called nitrites, and are much more stable compounds than the acid.

NITRIC ACID.



Preparation. Nitric acid is prepared by heating a mixture of sulphuric acid (H_2SO_4) and a nitrate, usually sodium nitrate (NaNO_3). The sulphuric acid unites with the sodium. Thus:



Properties :

a. *Physical.* Nitric acid is a colorless, fuming, corrosive, and poisonous fluid, heavier than water.

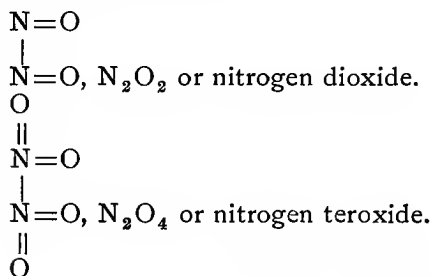
b. *Chemically* it is a powerful oxidizing agent. Many such substances as glycerine cotton, sugar, etc., are converted into explosives by the action of nitric acid. Mixed with hydrochloric acid (HCl), in the proportion of 1 to 3, it will dissolve gold, hence this mixture is called *aqua regia*.

When nitric acid contains some of the nitrous acid it is then called *fuming* nitric acid, for the nitrous acid decomposes and sets free nitrogen dioxide, which, combining with the oxygen of the air, forms yellowish fumes of nitrogen tetroxide (N_2O_4).

The union of nitric acid with bases forms nitrates, such as the nitrate of potash (KNO_3).

Uses. Nitric acid is used for etching, for the manufacture of explosives, and for oxidizing purposes.

Besides the regular oxides of nitrogen already considered, there are two others in which nitrogen having the equivalence of III. and V.—two of the bonds saturate each other. Thus :



NITROGEN DIOXIDE.

Formula : N_2O_2 .

Preparation. It is prepared by reducing nitric acid, HNO_3 , by metals, as copper, silver, etc. Thus :

CHAPTER IV.

CARBON.

Symbol C. Atomic weight 12. Equivalence II. and IV.

History. Carbon in one form or another has been known for centuries.

Occurrence. Carbon in the free state exists only as a solid, but in three distinct forms.

1. Diamond.
2. Graphite.
3. Coal.

Chemically these substances are the same, but physically entirely different.

In the combined state carbon exists in the air, limestone, petroleum, and in all animal and vegetable tissues.

DIAMOND.

History and occurrence. The diamond was found to consist only of carbon by Lavoisier, in 1776, who burned it in oxygen and obtained as a product of this combustion carbon dioxide (CO_2).

It is found principally in India and Brazil.

Preparation. Diamonds have never been prepared physically or chemically.

Properties :

a. *Physical.* The diamond is a crystalline, transparent, and solid body with a very high refractive and dispersive

power. It is the hardest substance known, and a very poor conductor of heat and electricity.

b. *Chemically* little is known of the diamond except that it is combustible at a high temperature, and composed of carbon alone.

Uses. Diamonds are used as ornaments and for cutting hard substances, such as glass, *for drills.*
Impure form, are called "brilliant".

GRAPHITE.

Occurrence. Graphite is found in the United States, England, Ceylon, and many other places as pure carbon.

Properties :

a. *Physical.* It is a crystallizable, soft, blackish solid, friable and oily to the touch. It is a good conductor of heat and electricity, and has a metallic lustre.

b. *Chemically* it is combustible only at high temperatures and with some difficulty, and is composed entirely of carbon.

Uses. It is used as a polish for metals, such as iron, preventing the formation of rust. It is also used in the manufacture of lead-pencils and crucibles.

COAL.

Carbon as coal exists in two varieties.

a. Charcoal.

b. Mineral coal.

CHARCOAL.

Occurrence. Charcoal is not found free in nature, but is the result of destructive distillation.

Preparation. It is obtained by heating animal or vegetable matter to redness in nearly closed vessels. In this

way the volatile matters are driven off, leaving the carbon behind.

Properties :

a. *Physical.* Charcoal is a black, porous, soft solid, and very light. It will absorb gases to a great extent, and is a good decolorizer.

b. *Chemically* it is a good oxidizer and very combustible.

Uses. It is used largely as a disinfectant by absorbing and oxidizing noxious gases, also as a decolorizing agent in refining sugar, and as a fuel.

MINERAL COAL.

Occurrence. It is found in nature as anthracite, bituminous, and cannel coal, the first being much the purest carbon. It is the result of geological changes taking place in primitive vegetation, and is thus the product of vegetable life; the anthracite variety is of the oldest formation.

Properties :

a. *Physical.* Coal is an amorphous, hard, black, heavy solid, with more or less lustre.

b. *Chemically* it is combustible with some difficulty, and is not composed of pure carbon.

Uses. Coal is used principally for heating and illuminating purposes.

All three forms of carbon are alike in being non-volatile, solid, and remaining unaltered in the air at ordinary temperatures. They are not subject to decay.

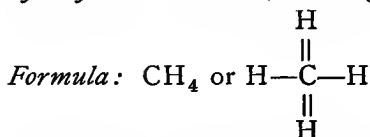
Compounds

I. OF CARBON AND HYDROGEN.

These compounds are called hydrocarbons, and many of them belong exclusively to organic chemistry.

HYDROGEN CARBIDE.

Synonyms. Methane, marsh gas, and fire-damp.



Occurrence. It occurs free in nature as "marsh gas" by the decomposition of vegetable matter under water, and also in coal mines as fire-damp.

Properties:

a. *Physical.* It is a colorless, odorless, and tasteless gas, slightly soluble in water, and next to hydrogen in lightness.

b. *Chemically* it is combustible, burning with a slightly luminous flame. With air it forms an explosive mixture. Methane forms the first of a homogeneous series of organic compounds with the general formula of $\text{C}_n\text{H}_{2n+2}$, that is, having twice as many hydrogen atoms as carbon, plus 2.

Uses. It is used in some localities as an illuminating agent.

HYDROGEN DICARBIDE.

Synonyms. Carburetted hydrogen, olefiant gas, and ethylene.

Formula: C_2H_4 .

Occurrence. It has been found free in nature among the gases in coal mines.

Preparation. It is prepared by the destructive distillation of coal in making illuminating gas.

Properties:

a. *Physical.* It is a colorless gas with a sweetish taste and odor. It is soluble in water and lighter than air.

b. *Chemical.* It is combustible, burning with a brilliant white but smoky flame. When mixed with oxygen it is very explosive.

Uses. For illuminating purposes principally.

DIHYDROGEN DICARBIDE.

Synonym. Acetylene.

Formula. H_2C_2 .

Preparation. Acetylene is prepared by the direct union of its constituents at a high temperature, as when the carbon points of the electrodes of a powerful chemical battery are brought near together in an atmosphere of hydrogen. It is produced in all cases of incomplete combustion.

Properties :

a. *Physical.* It is a colorless gas, soluble in water, and has a very disagreeable odor.

b. *Chemically* it is combustible, burning with a bright smoky flame.

It combines readily with some metals, as copper and silver, thus forming violently explosive compounds.

2. OF CARBON AND OXYGEN.

CARBON DIOXIDE.

Formula : CO_2 or $\text{C} = \text{O}$.

$$\begin{array}{c} \parallel \\ \text{O} \end{array}$$

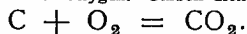
History. In 1520 Paracelsus discovered this gas, and it was the first one distinguished from the air.

Occurrence. It is found free in the air, especially in volcanic regions, and as it is a regular product of combustion and fermentation it is found in large quantities where such processes are going on.

It is often found in large quantities in low places, as at the bottom of wells, and called *choke damp*. In combination it exists in large quantities in limestone.

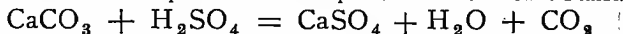
Preparation. It is always the product of combustion in presence of oxygen. Thus :

Carbon. Oxygen. Carbon dioxide.



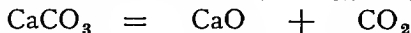
Chemically it is prepared by the action of acids, as sulphuric (H_2SO_4), on calcic carbonate (CaCO_3). Thus :

Calc. carbonate. Sulph. acid. Calc. sulphate. Water. Carb. dioxide.



It is produced in large quantities by burning calcic carbonate (CaCO_3). Thus :

Calc. carbonate. Calcic oxide. Carbon dioxide.

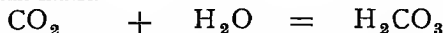


Properties :

a. *Physical.* Carbon dioxide is a colorless, odorless gas with an acid taste, very soluble in water, and $1\frac{1}{2}$ times heavier than air. It is fatal to life if breathed in large quantities.

b. *Chemically* it will not support combustion, and is non-combustible. By its solution in water it unites with a molecule of water to form carbonic acid (H_2CO_3). Thus :

Carbonic dioxide. Water. Carbonic acid.



This acid is readily decomposed by heat into H_2O and CO_2 .

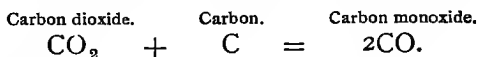
The salts of carbonic acid are carbonates, and are formed by replacing the hydrogen atoms by basic elements, as calcium, potassium, sodium, etc.

Uses. Soda waters and effervescent drinks are waters charged with carbon dioxide.

CARBON MONOXIDE.

Formula : CO.

Preparation. It is produced by incomplete combustion, or by passing carbon dioxide over heated carbon. Thus :



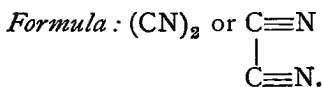
Properties :

a. *Physical.* It is a colorless gas with a suffocating odor, slightly soluble in water, and very fatal to animal life.

b. *Chemical.* It is combustible, burning with a blue flame, but will not support combustion. The gas will pass through heated cast-iron and in this way find egress into rooms from stoves or furnaces.

3. OF CARBON AND NITROGEN.

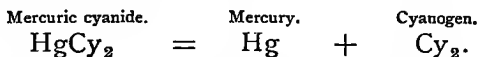
CYANOGEN.



Symbol. Cy.

History. It was the first compound radical isolated.

Preparation. It is prepared by heating cyanide of mercury (HgCy_2). Thus :



Properties :

a. *Physical.* It is a colorless, poisonous gas, with an odor resembling that of peach blossoms.

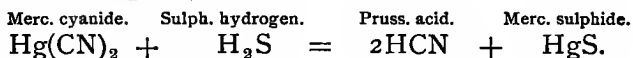
b. *Chemical.* It is combustible, burning with a bluish flame. Although we have cyanogen existing as such by saturation of its own bonds, still cyanogen (CN) is really a compound radical with an equivalence of one.

Thus by its union with potassium there results potassium cyanide (K-CN), with hydrogen, hydrogen cyanide (HCN), commonly called hydrocyanic acid or prussic acid.

HYDROCYANIC ACID.

Formula : HCN or H-CN.

Preparation. Prussic acid can be prepared pure by passing sulphurated hydrogen (H_2S) over dry mercuric cyanide $(Hg(CN)_2)$. Thus :



Properties :

Prussic acid is a volatile liquid with an odor like that of bitter almonds, which contains a little of the acid. It is the most deadly poison known.

There are a great many cyanogens, but they belong generally to the organic compounds, and hence treated of under Organic Chemistry.

CHAPTER V.

COMBUSTION.

Combustion, in the strict sense, is oxidation, but commonly speaking it is rapid oxidation or oxidation accompanied by heat and light.

Products of combustion :

The products of combustion are of two kinds :

Physical.

Chemical.

a. The *physical* products are heat and light.

b. The *chemical* products are always water (H_2O) and carbon dioxide (CO_2), the result of hydrogen and carbon burning in presence of oxygen.

ILLUMINATING GAS.

History. In 1792 Murdoch made gas illumination a success, it having been observed before this that the gases obtained from the distillation of coal were combustible.

Preparation. Illuminating gas is ordinarily prepared by heating bituminous coal to a high temperature, thus distilling off the combustible gases with their impurities.

The gas is first passed through pipes, thus condensing the water, gas-tar, and ammonia liquors. It is next passed through the "purifier," which is filled with dry, slacked lime (CaO), separating the other impurities from the gas, as sulphur compounds and carbon dioxide (CO_2).

The gas, now freed from impurities, is ready for use. Gas can also be prepared from wood, petroleum, peat, etc. That prepared from coal is sometimes passed over a carbonator, an apparatus by means of which heavy hydrocarbons are added to the gas from naphtha to make it more luminous.

Composition of illuminating gas. The principal gases constituting illuminating gas are :

1. Diluents.

H. 30 to 60%.

CH_4 . Marsh gas, 40 to 70%.

CO. Carbon monoxide, 7 to 13%.

2. Luminants:

C_2H_4 . Olefiant gas, 6 to 12%.

C_2H_2 . Acetylene, 6 to 12%

C_nH_{2n} . Hydrocarbons, 6 to 12%.

3. Impurities.

C.

S.

N.

CO_2 . Carbon dioxide.

Properties:

a. *Physical*. Illuminating gas is colorless, with a very disagreeable, suffocating odor. It is lighter than air and poisonous to animal life.

b. *Chemically* it is combustible, burning with a bright yellow flame. The collateral products from coal-gas manufacture are :

Coke,

Gas-tar,

Ammoniacal liquors.

Uses. The gases are used for illuminating purposes, the coke for fuel, the ammoniacal liquors for the manufacture

of ammonium salts, and the gas-tar for making anilines, phenols, and hydrocarbons.

ANIMAL AND VEGETABLE ECONOMY.

Animals, as a rule, produce in general those chemical substances which plants live upon, and plants produce, in their turn, articles of food for animals. Thus:

1. Animals produce and plants eat:

Carbon-dioxide, CO_2 .

Water, H_2O .

Ammonia, NH_3 .

Salts, especially salts of K, Na, and Ca.

2. Plants produce and animals eat:

Vegetable products,

Oxygen.

PLANTS CONTAIN :

Carbohydrates,

Fats,

Organic acids,

Resins,

Essential oils,

Alkaloids,

Albuminoids,

Water,

Inorganic salts.

ANIMALS CONTAIN :

Fats,

Albuminoids,

Water,

Salts.

CHAPTER VI.

HALOGEN GROUP.

Chlorine, bromine, iodine, and fluorine form a group of elements which resemble each other to a marked degree, both physically and chemically.

They all form salts that contain no oxygen and resemble sea salt, hence called *halogen salts*, and the elements *haloids*.

The ratio between their atomic weights, especially of the chlorine, bromine, and iodine, is nearly constant.

CHLORINE.

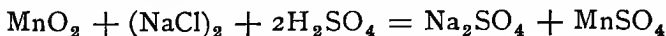
Symbol Cl. *Atomic weight* 35.5. *Equivalence* I.

History. Chlorine was discovered by Scheele in 1774.

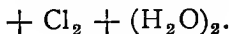
Occurrence. Chlorine never occurs free in nature, but always in combination. It is usually combined with potassium, sodium, magnesium, and other metallic elements. It exists largely in mineral springs and sea water. In the form of common salt (NaCl) it forms vast deposits in the earth's crust.

Preparation. It is largely prepared by the action of sulphuric acid (H_2SO_4) upon a mixture of common salt (NaCl) and manganese dioxide (MnO_2). Thus:

Mang. diox. Sod. chloride. Sulphuric acid. Sod. sulphate. Manganic sulphate.

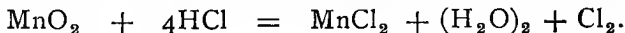


Chlorine. Water.



or by the action of hydrochloric acid (HCl) upon manganic oxide (MnO_2). Thus:

Manganic oxide. Hydrochloric acid. Manganous chloride. Water. Chlorine.



Properties :

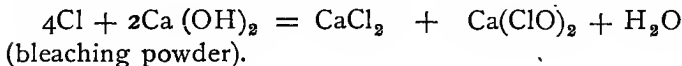
a. *Physical.* Chlorine is a yellowish green gas with a suffocating odor and astringent taste. It is very irritating to the air passages when inhaled, very soluble in water, and much heavier than air.

b. *Chemically* it is very active, combining directly with all elements except nitrogen, oxygen, and carbon.

It combines with free hydrogen in the presence of sunlight to form hydrochloric-acid gas (HCl), and with powdered copper, arsenic, antimony, and phosphorus with the evolution of heat and light. Chlorine is combustible in hydrogen gas, but not in oxygen. Chlorine is sometimes called an *allotropic* element—that is, being capable of existing in two different physical conditions, for in the dark it is much less active than in the light. Free chlorine is a good bleaching agent, for, owing to the attraction of chlorine for hydrogen, water is decomposed, and the oxygen set free, which destroys vegetable coloring matters by oxidizing them.

Bleaching powder is made from the action of chlorine on slacked lime. Thus:

Chlorine. Calcic hydrate. Calcic chloride. Calcic hypochlorite. Water.



Uses. Chlorine is used as a bleaching agent and for a disinfectant. The so-called chloride of lime is merely slacked lime impregnated with chlorine gas.

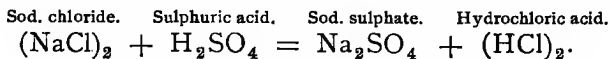
Compounds.

1. CHLORINE AND HYDROGEN.

HYDROGEN CHLORIDE OR HYDROCHLORIC ACID.

Formula. HCl or H-Cl.

Preparation. Hydrogen chloride may be prepared by direct union of its constituents by mixing equal volumes of chlorine and hydrogen gases, and exposing them to the sunlight. It is commercially made by the action of sulphuric acid (H_2SO_4) on common salt (NaCl). Thus:

*Properties :*

a. *Physical.* Hydrogen chloride is a colorless, pungent acid gas turning blue litmus red, very soluble in water, forming hydrochloric acid.

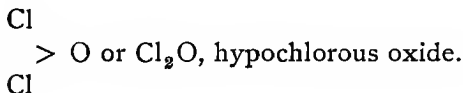
b. *Chemically* the gas is non-combustible.

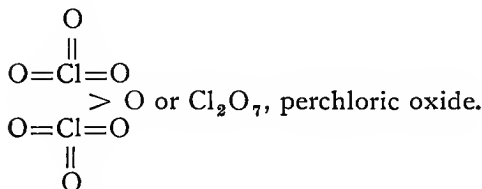
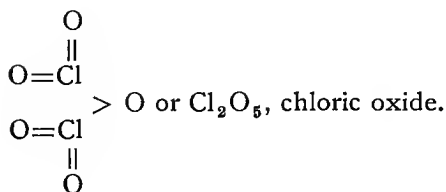
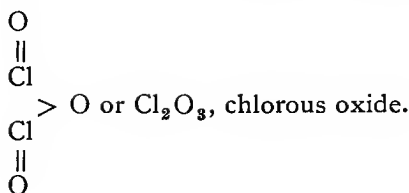
The liquid acid dissolves many of the metallic oxides, as antimony, iron, tin, zinc, etc., forming chlorides.

Uses. Hydrochloric acid is used principally for chemical purposes.

2. OF CHLORINE AND OXYGEN.

As chlorine may be a monad, triad, pentad, or heptad, its union with the (monad) oxygen will result in the formation of four oxides. Thus :

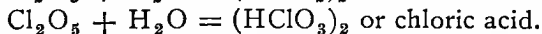




From these oxides acids are formed on the plan of the water type by substituting two hydroxyls (OH) for an atom of oxygen in each of the oxides, or, which results in the same formula, adding one molecule of water. Thus:



$\text{Cl-OH or (HClO)}_2 = \text{Cl}_2\text{O} + \text{H}_2\text{O (HClO)}_2$ hypochlorous acid.

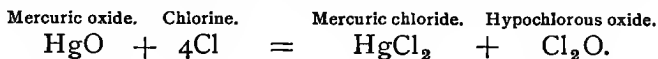


The salts of the acids are formed theoretically as usual by replacing the hydrogens with basic elements.

HYPOCHLOROUS OXIDE AND ACID.

Formula : Cl_2O .

Preparation. It is prepared by passing free chlorine over mercuric oxide, HgO .



Properties :

a. *Physical.* It is a yellowish gas with an odor like free chlorine; very soluble in water.

b. *Chemically* it is a very unstable compound, decomposing easily into chlorine and oxygen. It combines with water to form *hypochlorous acid* (HClO), which is a very powerful bleaching agent.

The salts of this acid are called hypochlorites, and are used for bleaching agents and disinfectants, as, for instance, the calcium hypochlorite, $\text{Ca}(\text{ClO})_2$, or solutions of sodium hypochlorite, NaClO (Fabarraque solution), and pot. hypochlorite, KClO (Javelle water).

CHLOROUS OXIDE AND ACID.

Formula : Cl_2O_3 .

Preparation. Chlorous oxide is prepared by reducing the chlorates by action of nitric acid (HNO_3) in presence of a reducing agent, as arsenious acid.

Properties :

a. *Physical.* It is a greenish gas, with a suffocating odor, and very soluble in water.

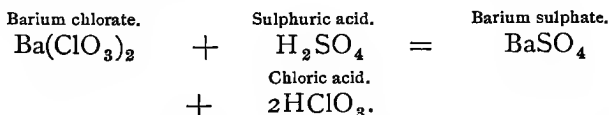
b. *Chemically*, it is a good bleaching agent, and unites with water, forming *chlorous acid* (HClO_2).

This compound is very unstable, as are its corresponding salts the chlorites, as potassium chlorite (KClO_2).

CHLORIC ACID.

Formula : HClO_3 .

Preparation. Chloric acid is prepared by the action of sulphuric acid (H_2SO_4) upon barium chlorate $\text{Ba}(\text{ClO}_3)_2$. Thus:



Properties. Chloric acid is a very powerful oxidizing agent. It will set paper on fire when dropped upon it. The salts of this acid form chlorates, and are also strong oxidizing agents.

Uses. The acid and its salts are used as oxidizing agents, and in making pyrotechnical mixtures. Potassium chlorate is used in making oxygen.

PERCHLORIC ACID.

Formula : HClO_4 .

Preparation. Perchloric acid is prepared by heating perchlorate of potassium (KClO_4) with sulphuric acid (H_2SO_4).

Properties :

a. *Physical.* It is an oily, colorless, fuming liquid, with an odor of chlorine.

b. *Chemical.* It is a powerful oxidizing agent, setting paper and wood on fire when dropped upon them. Chloric acid and its corresponding salts are the most stable of the chlorine acids and salts.

BROMINE.

Symbol Br. *Atomic weight* 80. *Equivalence* 1.

History. Bromine was discovered in the water of the Mediterranean Sea in 1826 by Ballad.

Occurrence. Bromine does not occur free in nature, but in combination with metallic elements, as sodium and magnesia; it is found in sea water and many mineral springs.

Preparation. It is prepared by evaporating water rich in bromides until the salts are separated by crystallization, and exposing these to chlorine, which decomposes them, setting bromide free.

Properties:

a. *Physical.* Bromine is a dark, heavy liquid, with a suffocating odor.

b. *Chemically,* it is analogous to chlorine, but less active.

Uses. Bromine is used in photography, and as a bleaching and disinfecting agent.

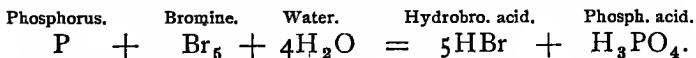
Compounds.

a. HYDROGEN AND BROMINE.

HYDROGEN BROMIDE OR HYDROBROMIC ACID.

Formula: HBr or $\text{H}-\text{Br}$.

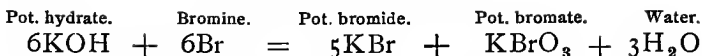
Preparation. Hydrobromic acid is prepared by bringing phosphorus and bromine together in presence of water, when they unite with a loud explosion. Thus:



Properties:

a. *Physical.* Hydrobromic acid is a fuming, colorless gas, with an acid reaction, and very soluble in water.

The principal salt of this acid is potassium bromide, KBr . It is prepared by heating caustic potash, KOH with bromine.



2. BROMINE AND OXYGEN.

Theoretically, there are oxides and acids of bromine as there are of chlorine, but chemically there are not so many.

Thus there is hypobromous acid (HBrO) and bromic acid (HBrO₃), and from them their corresponding salts, formed by replacing the hydrogens by basic elements, as calcium, forming calcium hypobromite, Ca-(BrO)₂, and calcium bromate, Ca(BrO₃)₂.

IODINE.

Formula I. Atomic weight 127. Equivalence I.

History. Iodine was discovered in 1811 by Courtois, in sea water.

Occurrence. Iodine does not occur free in nature, but is combined with metals in sea water, and with sodium and magnesium in sea-weed.

Preparation. Iodine is prepared by burning sea-weed, and dissolving this ash or kelp in water, and thus obtaining the bitter or mother liquid. From this it is obtained by a process analogous to that of preparing chlorine.

Properties:

a. *Physical.* Iodine is a black crystalline solid, with a metallic lustre. Heated, it evolves the heaviest vapor known. Iodine is but slightly soluble in water, but readily in alcohol.

b. *Chemically,* it is similar to bromine and chlorine, but less active than either. Free iodine turns starch solutions a deep-blue color.

Uses. Iodine is used principally in photography and medicine.

Compounds.

I. HYDROGEN AND IODINE.

HYDROIODIC ACID.

Formula: HI or H—I.

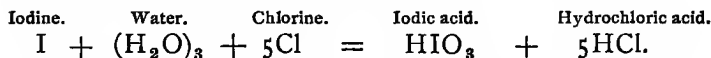
Preparation. This acid is prepared, as is also the salt pot. iodide, in the same manner as the corresponding acid and salt of bromine. The reactions are similar, simply substitute one body for the other.

Properties. Hydroiodic acid is a colorless, fuming acid gas, which is soluble in water.

2. OF IODINE AND OXYGEN.

As there are oxides and acids of chlorine and bromine so there are of iodine, the most important of which is *iodic acid* (HIO_3).

Preparation. Iodic acid may be prepared by oxidizing iodine with nitric acid (HNO_3), or by acting upon iodine water with chlorine gas. Thus :



Properties.

Iodic acid is a colorless, crystalline solid, slightly soluble in water.

FLUORINE.

Symbol F. *Atomic weight* 19. *Equivalence* I.

Occurrence. Fluorine is found in nature combined with calcium, forming calcium fluoride (CaF_2) or "fluorspar"; with sodium (NaF); and aluminum (AlF_3), forming cryolite.

Preparation. Fluorine has ~~never~~ been obtained in a free state.

Properties. Fluorine has never been known to combine with oxygen.

Compounds.

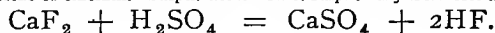
HYDROGEN AND FLUORINE.

HYDROFLUORIC ACID.

Formula: HF, or H—F.

Preparation. Hydrofluoric acid is prepared by acting upon fluorspar by sulphuric acid. Thus:

Fluoride of calcium. Sulph. acid. Calc. sulph. Hydrofluoric acid.



Properties:

a. *Physical.* It is a colorless, fuming acid gas, very irritating to the air tubes when inhaled, and it is more or less corrosive.

b. *Chemically,* it has the power of attacking glass by uniting with the silicon to form silicon fluoride.

Uses. Hydrofluoric acid is used extensively in etching glass.

CHAPTER VII.

SULPHUR.

Symbol S. *Atomic weight* 32. *Equivalence* II-IV.

History. Sulphur has been known from remote ages.

Occurrence. It occurs free as native sulphur in many volcanic regions.

In combination it occurs with iron, zinc, arsenic, and many other mineral and metallic elements. It is also found in all animal and many vegetable tissues.

Preparation. It is prepared by roasting native sulphur or combined sulphur in furnaces, thus driving off the pure sulphur as a vapor, which collects on the sides of the receiver as *flowers of sulphur*. Some of it is condensed into a liquid, which is collected in moulds, where it hardens, forming *roll sulphur*, or brimstone.

Precipitated sulphur, or *lac sulphur*, is made by adding an acid to a solution of boiling sulphur and milk of lime.

Properties :

a. *Physical.* Sulphur occurs in three allotropic forms, viz.:

1. The variety found in nature, which is a brittle crystalline solid, insoluble in water but soluble in carbon disulphide (CS_2).

2. The second variety is that obtained by the crystallization of sulphur fused at a high temperature.

It occurs as yellowish-brown transparent crystals, insoluble in carbon disulphide, but changes slowly into variety 1.

3. The third variety is obtained by pouring melted sulphur into water; this forms a dark tenacious mass which can be drawn out into threads. It is insoluble in carbon di-sulphide, but slowly changes to variety 1.

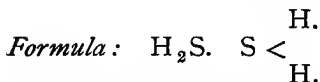
b. *Chemical.* Sulphur is combustible at a temperature of 260° C., burning with a blue flame and forming sulphur dioxide (SO_2). Its vapor supports combustion, uniting with metals to form sulphides.

Uses. Sulphur is used for making sulphuric acid (H_2SO_4), and its vapor for bleaching straws.

Compounds.

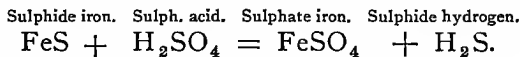
I. SULPHUR AND HYDROGEN.

HYDROGEN SULPHIDE.



Occurrence. Hydrogen sulphide exists in volcanic gases and sulphur springs, and is a product of decomposition.

Preparation. It can be prepared by direct union of its constituents by means of heat, but it is usually made by the action of sulphuric acid (H_2SO_4) on sulphide of iron (FeS). Thus:



Properties:

a. *Physical.* It is a colorless gas with an odor of rotten eggs. It is heavier than air and very soluble in water. It is quite poisonous to animal life.

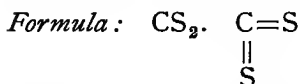
b. *Chemically* it is combustible, burning with a blue flame. It is easily decomposed by oxidizing agents. It

unites with metallic bases and their oxides to form sulphides.

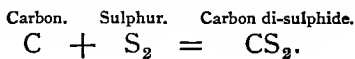
Uses. It is used in laboratories as a reagent, uniting with metallic elements in solution to form insoluble sulphides, which have various colors.

2. OF CARBON AND SULPHUR.

CARBON DI-SULPHIDE.



Preparation. Carbon di-sulphide is best prepared by passing sulphur vapor over red-hot charcoal. Thus:



Properties:

a. *Physical.* It is a liquid with an ethereal odor when pure, but when impure has a very disagreeable odor. It is not soluble in water, and has strong refractive properties.

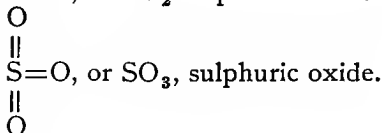
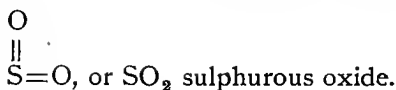
b. *Chemical.* When vaporized it is combustible, burning with a bright blue flame. It has remarkable solvent properties, dissolving phosphorus, iodine, sulphur, resins, fats, etc.

Uses. It is used principally as a solvent, for extracting oils and fats, and for lenses.

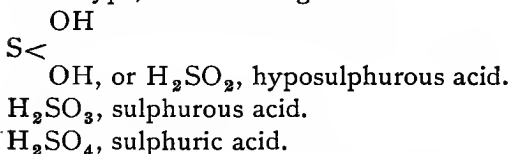
3. OF SULPHUR AND OXYGEN.

As sulphur may be a diad, tetrad, or hexad, there result from its union with oxygen the following oxides.

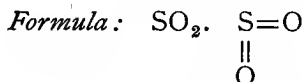
$\text{S}=\text{O}$, or SO , hyposulphurous oxide.



From these oxides there are formed, on the plan of the water type, the following acids:

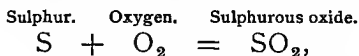


SULPHUROUS OXIDE AND ACID.

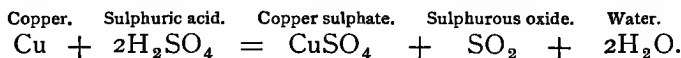


Occurrence. Sulphurous oxide is found free in volcanic gases.

Preparation. It is always formed by the combustion of sulphur in the presence of oxygen. Thus:



or by the reduction of sulphuric acid by copper. Thus:



Properties.

a. *Physical.* Sulphurous oxide, or commonly called sulphur di-oxide, is a pungent gas with a suffocating odor; twice heavier than air and freely soluble in water.

b. *Chemical.* It is not combustible or a supporter of combustion. It unites with metallic oxides to form sulph-

ites. Combining with a molecule of water it forms sulphurous acid, which is a liquid having an acid reaction. It is a fine bleaching agent, owing to its affinity for oxygen, thus uniting with the oxygen of the water or coloring agents, decomposing the compounds, and setting free hydrogen; best bleaching agent for woollens and silks.

Sulphurous acid (H_2SO_3) is a reducing agent, owing to its affinity for oxygen, which combines with the sulphurous acid to form sulphuric acid. By replacing one or more of the hydrogens in sulphurous acid by basic elements, sulphites are formed. When only one of two hydrogens is thus replaced the product is called an acid salt.

Uses. Sulphurous oxide is a good disinfectant for sick-rooms. The acid and salts are used for bleaching woollens and preserving cider, fruits, etc.

SULPHURIC OXIDE.

Formula: SO_3 or $\text{O}=\text{S}=\text{O}$.

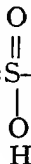


Preparation. Sulphuric oxide is prepared by oxidizing sulphurous oxide by means of heat.

Properties. It is a wax-like solid—crystallizing, thus resembling asbestos. It melts at 16°C ., forming the fluid oxide which has the highest co-efficient of expansion known. It unites with water with great heat, forming sulphuric acid (H_2SO_4).

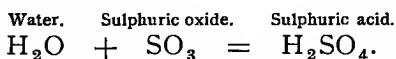
SULPHURIC ACID.

Formula: H_2SO_4 or $\text{O}=\text{S}-\text{OH}$



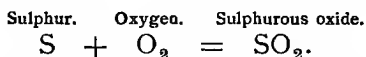
Occurrence. It occurs free in some mineral springs, and in the secretions of many animals. Combined with metallic elements it occurs in great abundance.

Preparation. It may be prepared by adding water to sulphuric oxide. Thus:

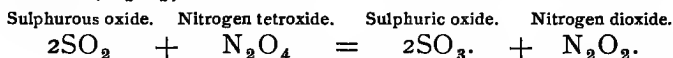


Commercially it is prepared by the four following steps:

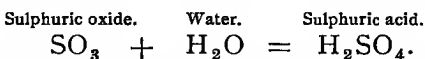
1. Sulphur is burned in the air, thus producing sulphurous oxide. Thus:



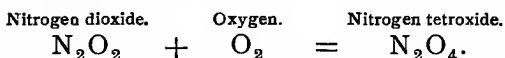
2. This sulphurous oxide (SO_2) is then mixed with nitrogen tetroxide, forming sulphuric oxide and nitrogen dioxide (N_2O_2). Thus:



3. This sulphuric oxide (SO_3) is then mixed with steam (H_2O), which unites with it, forming sulphuric acid (H_2SO_4). Thus:



4. The nitrogen tetroxide (N_2O_4) is obtained again for use by reoxidation of nitrogen dioxide (N_2O_2). Thus:



The N_2O_2 is made by adding nitric acid, HNO_3 , to copper. See page 129.

Properties :

a. *Physical.* Sulphuric acid is a colorless, oily, corrosive liquid, much heavier than water. It is decomposed at high temperatures, and has strong affinity for water.

It will extract moisture from the air, drying it; and from organic matter, charring it.

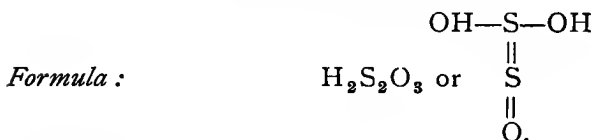
b. *Chemically*, one or more of its hydrogens may be replaced by basic elements forming sulphates, which are very stable compounds.

Uses. Sulphuric acid is principally used in the manufacture of chemicals, as nitric, hydrochloric, phosphoric, and other acids, and commercial products.

THIONIC ACIDS.

There are a few sulphur acids—but of little importance—which are formed of two atoms of sulphur combining with oxygen and hydrogen instead of one. Thus :

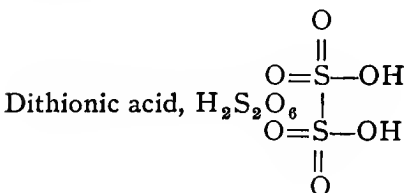
THIO-SULPHURIC ACID.



Properties :

The salts formed from this acid used to be called hypsulphites, the most important of which is sodium thio-sulphate, $\text{Na}_2\text{S}_2\text{O}_3$, formed by replacing the hydrogen by the metallic element sodium.

Uses. This salt is used as a medicine and in photography.



and pyro-sulphuric acid, $\text{H}_2\text{S}_2\text{O}_7$, are the other acids of sulphur whose salts, as pyro-sulphate of sodium, $\text{Na}_2\text{S}_2\text{O}_7$, are used in the arts and pharmacy.

Fuming or *pyro-sulphuric acid* $\text{H}_2\text{S}_2\text{O}_7$ is a mixture of sulphuric acid H_2SO_4 and sulphuric oxide, SO_3 .

CHAPTER VIII.

SILICON AND BORON.

SILICON.

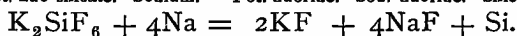
Symbol Si. *Atomic weight* 28. *Equivalence* IV.

History. Silicon was first obtained pure by Berzelius in 1823.

Occurrence. It does not occur free in nature, but in combination with oxygen, aluminum, potassium, etc., it forms a large portion of the rocks making up the earth's crust.

Preparation. Silicon is prepared by the action of sodium (Na) upon potassium fluo-silicate (K_2SiF_6). Thus:

Pot. fluo-silicate. Sodium. Pot. fluoride. Sod. fluoride. Silicon.



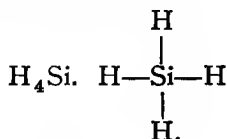
Properties. It is an amorphous, lustreless powder, very hard, and melting only at a very high temperature. At a still higher temperature it takes fire, forming, by its combustion, silicic oxide.

Compounds :

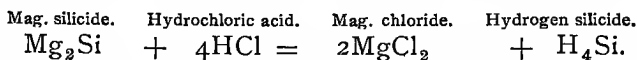
I. OF SILICON AND HYDROGEN.

HYDROGEN SILICIDE.

Formula.



Preparation. It is prepared by the decomposition of magnesium silicide, Mg_2Si , by hydrochloric acid, HCl . Thus :



Properties. It is a colorless gas, burning with a white flame upon coming in contact with oxygen, thus forming white clouds of silica (SiO_2) and water.

2. OF SILICON AND OXYGEN.

SILICA OR SILICON OXIDE.

Formula: SiO_2 .

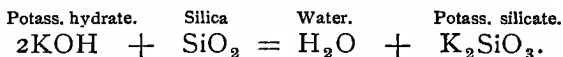
Occurrence. Silica occurs abundantly in nature as crystalline quartz, opal, amethyst, agate, etc. It also occurs as sand-stone. In combination with metallic oxides forming silicates it is very abundant. It is found dissolved in many mineral waters, and as a constituent of many animal and vegetable tissues.

Preparation. It is prepared by the oxidation of silicon or by the dehydration of silicic acid, H_2SiO_3 .

Properties:

a. *Physical.* Silica occurs in two forms, the crystalline and amorphous. It is very hard and will scratch glass. It is but slightly soluble in water and only in one acid, hydrofluoric (HF). It is fusible but only at very high temperatures.

b. *Chemical.* Silica heated with sodium or potassium hydrate under pressure will dissolve and form "fluid glass," or sodium or potassium silicate. Thus :



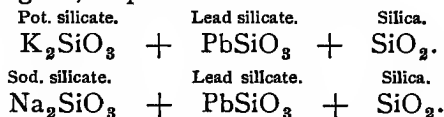
If an acid is added to this silicate it will decompose,

and uniting with the hydrogen of the acid form *silicic acid*, H_4SiO_4 . This acid is a gelatinous substance, not very stable, for it loses a molecule of water upon standing, forming what is called *meta-silicic acid*, H_2SiO_3 .

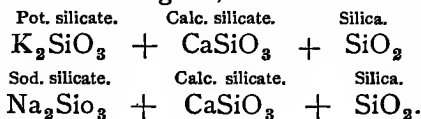
By replacing one or more of the hydrogens of either acid by a basic element, silicates are formed. The sodium and potassium meta-silicates are soluble in water.

Glass is a double silicate, and there are two principal varieties.

a. Flint glass, or potassio-lead silicate.



b. Crown or window glass, or sodio-calcic silicate.



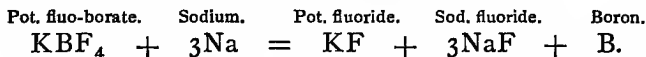
BORON.

Symbol B. Atomic weight 11. Equivalence III.

History. The salts of boron have been known for centuries, but pure boron was obtained in 1808.

Occurrence. It does not occur free in nature, but in combination with sodium, potassium, and ammonia it is found in many mineral waters, and as mineral deposits in the earth's crust.

Preparation. It is prepared by the action of sodium (Na) on potassium fluo-borate (KBF_4). Thus:



Properties. Boron is a chocolate-colored powder slightly

soluble in water. By dissolving it in aluminum it will crystallize, forming a solid having many of the physical properties of the diamond.

Compounds.

1. OF BORON AND OXYGEN.

BORIC ACID.

Formula: B_2O_3 .

Preparation. It is produced by the combustion of boron or boracic acid, H_3BO_3 , in presence of oxygen.

Properties. Boric oxide is a colorless, brittle, transparent acid.

2. OF BORON AND HYDROGEN.

BORIC OR BORACIC ACID.

Formula: H_3BO_3 or $OH-B \begin{smallmatrix} \text{OH} \\ \text{OH} \end{smallmatrix}$.

Occurrence. Boric acid occurs free in nature, especially in solution in the waters of volcanic regions.

Preparation. It is easily prepared by evaporating the waters holding it in solution.

Properties:

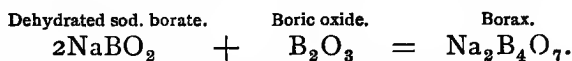
a. *Physical.* It occurs as white crystalline scales, soluble in water and having an acid reaction.

b. *Chemical.* By replacing one or more of the hydrogens by basic elements, borate salts are formed.

Thus sodium borate (NaH_2BO_3) is formed by replacing one hydrogen. The hydrogen contained in this salt is combined with oxygen in the form of water, and can be driven off by heat ($H_3BO_3-H_2O$).

Meta-Boracic Acid, HBO_2 ($H_3BO_3 - H_2O$).

Borax or fused sodium borate ($\text{Na}_2\text{B}_4\text{O}_7$) is a combination of the sodium meta-borate (NaBO_2), and boric oxide B_2O_3 . Thus:



Borax and boric acid are antiseptic and used in preserving articles.

CHAPTER IX.

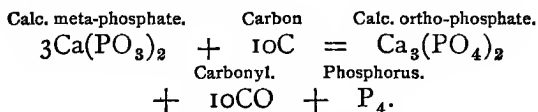
PHOSPHORUS.

Symbol P. *Atomic weight* 31. *Equivalence* I-III-V.

History. Phosphorus was discovered by Brant in 1669, from urine.

Occurrence. Phosphorus does not occur free in nature, but usually in combination with calcium, magnesium, and lead.

Preparation. Burnt bone is allowed to macerate in sulphuric acid (H_2SO_4) for some hours. This extracts from the bones phosphorus in the form of acid calcium phosphate, $\text{CaH}_4(\text{PO}_4)_2$, which remains in solution, and is poured off from the remainder of the mixture and evaporated to a syrupy consistency, being converted into the meta-phosphate $\text{Ca}(\text{PO}_3)_2$. This is next mixed with charcoal and heated to redness—the phosphorus distils over and is condensed. Thus :



Properties.

a. *Physical.* Phosphorus exists in two allotropic forms. In its usual form it is a colorless, transparent, and waxy substance with a peculiar odor. It is insoluble in water, but soluble in ether, alcohol, oils, and carbon di-sulphide.

b. *Chemical.* It oxidizes readily and burns in the air, hence must be kept under water. Owing to slow combus-

tion it is luminous in the dark and forms phosphorous oxide (P_2O_3). By rapid combustion it forms phosphoric oxide (P_2O_5). By heating this form of phosphorus to $250^\circ C$. it is converted into the other allotropic state.

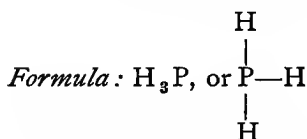
This form of phosphorus is a chocolate-red powder insoluble in ordinary solvents, does not oxidize readily in the air, has no odor, is not poisonous, does not burn easily, and will not shine in the dark.

Uses. Phosphorus is used principally in matches—both forms of phosphorus being employed.

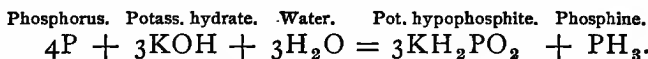
Compounds.

I. OF PHOSPHORUS AND HYDROGEN.

HYDROGEN PHOSPHIDE OR PHOSPHINE.



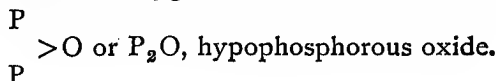
Preparation. Phosphine is usually prepared by boiling phosphorus with a solution of caustic potash (KOH). Thus:

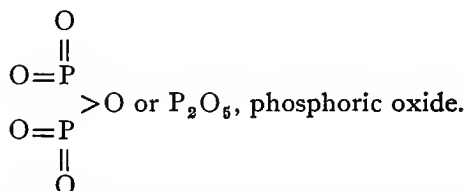
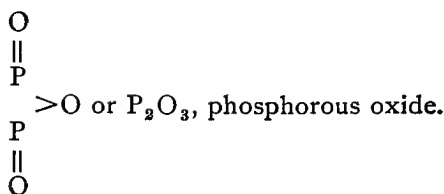


Properties. Phosphine is a colorless gas with a garlic-like odor, slightly soluble in water, and burns with a brilliant flame.

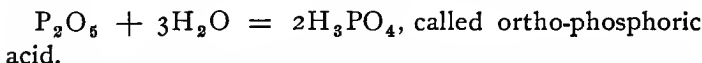
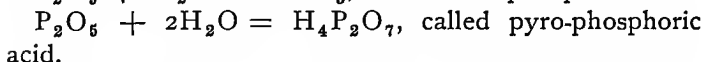
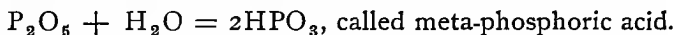
2. OF PHOSPHORUS AND OXYGEN.

As phosphorus has an equivalence of I, III, and V, by its union with oxygen three oxides are formed. Thus:





There are three well-known acids formed from the *ic* oxide by substituting two hydroxyls for 1, 2, and 3 of the oxygen atoms, or, in other words, by adding 1, 2, and 3 molecules of water. Thus:



These terms are applied for convenience to the acids of P. without relation to the usual meaning of the words ortho and pyro.

PHOSPHORIC OXIDE.

Formula: P_2O_5 .

Preparation. Phosphoric oxide is prepared by the rapid combustion of phosphorus in the air. $\text{P}_2 + \text{O}_5 = \text{P}_2\text{O}_5$.

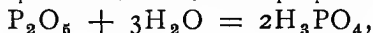
Properties. It is a white, amorphous powder, attracting moisture from the air and dissolving in water with a hissing noise, forming ortho-phosphoric acid (H_3PO_4).

ORTHO-PHOSPHORIC ACID.

Formula: H_3PO_4 .

Preparation. Ortho-phosphoric acid is prepared by adding boiling water to phosphoric oxide (P_2O_5). Thus:

Phosphoric oxide. Water. Ortho-phosphoric acid.



or it can be prepared by the oxidation of phosphorus with nitric acid.

Properties. Phosphoric acid is a clear, syrupy liquid with an acid reaction.

As there are three hydrogens that can be replaced by basic elements, it follows that there are three varieties of salts that can be formed, viz.: acid, normal, and double (see Theoretical Chemistry), and that the salts may be mono-, di-, or tri- basic.

Thus calcium is a diad and will take the place of two hydrogens, hence $\text{Ca}_2\text{H}_4(\text{PO}_4)_2$ is mono-calcic-ortho-phosphate or super-phosphate and an acid salt. *Again*, di-calcic-ortho-phosphate must be an acid salt with a formula $\text{Ca}_2\text{H}_2(\text{PO}_4)_2$, for to saturate two atoms of calcium it will take four atoms of hydrogen, and as there are only three in the acid two molecules must be taken, or $\text{H}_6(\text{PO}_4)_2$, to combine with the calcium. *Again*, tri-calcic-ortho-phosphate, or bone phosphate, is $\text{Ca}_3(\text{PO}_4)_2$ and a normal salt.

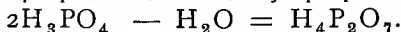
Ammonium - magnesium - ortho - phosphate $(\text{NH}_4) \text{Mg} \text{PO}_4$ is a double salt of ortho-phosphoric acid. *triple ph*

PYRO-PHOSPHORIC ACID.

Formula: $\text{H}_4\text{P}_2\text{O}_7$.

Preparation. This acid is prepared by heating phosphoric acid, H_3PO_4 , to 215°C ., and thus driving off a molecule of water. Thus:

Ortho-phosphoric acid. Water. Pyro-phosphoric acid.



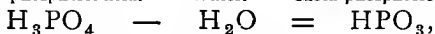
Properties. Pyro-phosphoric acid is a clear fluid substance with an acid reaction. By substituting for the hydrogens in this acid, basic elements, different kinds of pyro salt are formed, as are ortho salts from ortho-phosphoric acid. Thus: $\text{Na}_4\text{P}_2\text{O}_7$ is normal, and $\text{Na}_2\text{H}_2\text{P}_2\text{O}_7$ acid, sodium pyro-phosphate.

META-PHOSPHORIC ACID.

Formula: HPO_3 .

Preparation. Meta-phosphoric acid is prepared by heating ortho-phosphoric acid to redness, thus driving off a molecule of water.

Ortho-phosphoric acid. Water. Meta-phosphoric acid.



or by dissolving phosphoric oxide (P_2O_5) in water. Thus:

Phosphoric oxide. Water. Meta-phosphoric acid.



Properties:

This acid is a transparent ice-like solid, soluble in water and with an acid reaction. As it contains but one hydrogen, it forms but one class of salts—normal.

PHOSPHOROUS OXIDE.

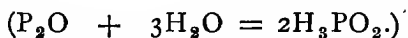
Formula: P_2O_3 .

Preparation. It is formed by the incomplete oxidation of phosphorus.

Properties. It is a volatile, white, flaky solid, with a peculiar odor. It dissolves in water with a hissing noise.

HYPOPHOSPHITES.

By adding three molecules of water to hypophosphorous oxide there is formed theoretically hypophosphorous acid H_3PO_2 .



By substituting basic elements in place of the hydrogens, salts are formed called hypophosphites—used in medicine.

CHAPTER X.

ALKALINE METALS.

Metals are distinguished from the non-metallic elements by their lustre, ductility, malleability, and tenacity; by being good conductors of heat and electricity, and electro-positive. They form in union with themselves *alloys*, but when they unite with non-metals they lose all metallic properties and form bases.

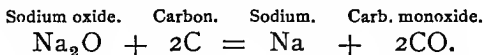
Alkaline metals have the property of turning litmus blue and turmeric brown. They saponify fats, neutralize acids, cauterize the skin, and are six in number, lithium, potassium, sodium, ammonium, caesium, and rubidium.

SODIUM.

Symbol Na. *Atomic weight* 23. *Equivalence* I.

Occurrence. Sodium is a very abundant element in nature. It occurs largely as a chloride in rock salt and sea water. It also occurs as a carbonate, borate, silicate, etc.

Preparation. Sodium is prepared by reducing its oxide (Na_2O) at a white heat with carbon. Thus:

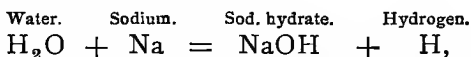


Properties. Sodium is a silvery-white soft metal. It decomposes water and oxidizes readily in the air, hence must be kept in some such solution as naphtha. By appli-

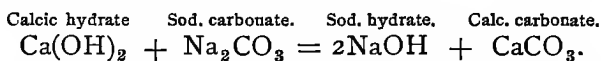
cation of heat, sodium burns with a yellow flame, forming sodium oxide Na_2O .

Uses. Sodium is used in metallurgy as a reducing agent.

Compounds. Sodium chloride or common "salt" (NaCl) is obtained by evaporating saline waters or by mining it in the form of rock salt. Sodium hydrate or "caustic soda" (NaOH) is prepared by the decomposition of water by metallic sodium. Thus:

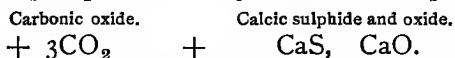
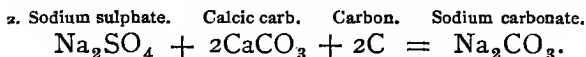
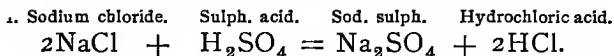


or by the action of calcium hydrate $\text{Ca}(\text{OH})_2$ upon sodium carbonate, Na_2CO_3 . Thus:



It is a very deliquescent white salt, coagulating albumen and having caustic properties. Sodium nitrate or "soda saltpetre" (NaNO_3) is a white salt very soluble in water and used in medicine.

Sodium carbonate or "soda," Na_2CO_3 , was formerly obtained from the ashes of sea-weed, but is now obtained by the famous *Leblanc soda process* as represented in the following formulæ. Thus:



"Baking powder" is acid super- or bi-carbonate of soda (NaHCO_3).

Sodium sulphate (Na_2SO_4). Its preparation is represented in the first formula of Leblanc's soda process.

The acid sodium sulphate (NaHSO_4) is prepared by adding sulphuric acid to the normal salt (Na_2SO_4). All the sodium salts are soluble in water.

POTASSIUM.

Symbol K. Atomic weight 39. Equivalence 1.

Occurrence. Potassium always occurs in combination, usually as a chloride, nitrate, or sulphate. It occurs in all vegetable tissues.

Preparation. It is prepared in a manner analogous to that of obtaining sodium, but is a more dangerous process, as the metal is apt to combine with carbonic monoxide (CO), which forms an explosive mixture.

Properties. Potassium is a soft bluish white metal, and has properties similar to those of sodium.

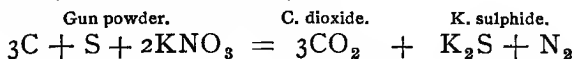
Compounds. Potassium chloride (KCl) occurs native and is prepared from sea water. It is much like sodium chloride (NaCl).

Potassium bromide (KBr) and iodide (KI) are prepared by the direct action of bromine and iodine upon potassium hydrate (KOH).

Both salts are used extensively in medicine. Potassium hydrate (KOH) or "caustic potash" is prepared in sticks, which are very deliquescent and have caustic properties coagulating albumen.

Potassium chlorate (KClO_3) is used extensively in the preparation of oxygen.

Potassium nitrate or "nitre" (KNO_3) occurs native upon the surface of soils in Bengal. Potassium sulphate (K_2SO_4) is used extensively in the manufacture of gunpowder ($3\text{C} + \text{S} + 2\text{KNO}_3$).



Potassium carbonate, "potash," or "pearlash" (K_2CO_3) is prepared by evaporating the leachings of wood ashes.

Potassium bicarbonate, called acid super- or bi-carbonate of potash, is used extensively in bread-making under the name of "saleratus."

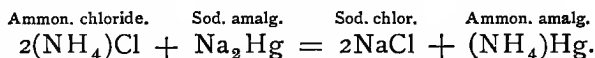
All potassium salts are soluble in water and have an alkaline reaction.

AMMONIUM.

Symbol NH_4 . *Molecular weight* 18. *Equivalence* I.

Properties. Ammonium is not an element but is really a compound radical with an equivalence of I. It acts as a basic element with an equivalence of I replacing the hydrogens in acids to form salts.

Ammonium has never been isolated except as an amalgam $(NH_4)_2Hg$, which is prepared thus:



Compounds. Ammonium chloride or "sal ammoniac," $(NH_4)Cl$, is obtained by heating the ammoniacal liquors from coal distillation with hydrochloric acid (HCl).

All the ammonium salts, as the carbonate, $(NH_4)_2CO_3$, nitrate, $(NH_4)NO_3$ and sulphate $(NH_4)_2SO_4$ are soluble in water, alkaline in reaction, and volatile.

Aqua Ammonia is ammonia (NH_3), dissolved in water. Thus:

$NH + 3H_2O = NH_4OH$. It has all the properties of caustic soda or potash, but will not saponify fats and is volatile.

LITHIUM.

Symbol Li. *Atomic weight* 7. *Equivalence* I.

Occurrence. Lithium occurs usually as a chloride in

mineral and sea waters. It is also found sparingly in some minerals.

Preparation. It is best prepared from the chloride of lithium, LiCl , by electrolysis.

Properties. Lithium is a soft, light, and silvery-white metal. It tarnishes in the air, decomposes water, and burns with a white flame at high temperatures.

Compounds. Many of the lithium compounds are volatile and burn with a brilliant crimson flame. All of its salts are soluble in water, but the carbonate of lithium, Li_2CO_3 , sparingly so. All of the watery solutions of lithium salts have an alkaline reaction, and many are used in medicine.

CHAPTER XI.

ALKALINE EARTHS.

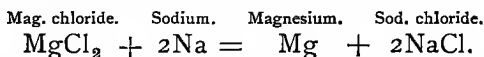
MAGNESIUM, STRONTIUM, BARIUM, CALCIUM.

MAGNESIUM.

Symbol Mg. *Atomic weight* 24. *Equivalence* II.

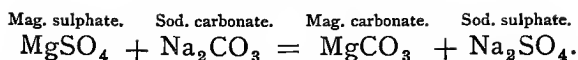
Occurrence. Magnesium is always found in combination, usually as a hydrate, carbonate, silicate, borate, or chloride.

Preparation. It is best prepared by heating magnesium chloride (MgCl_2) with sodium. Thus:



Properties. Magnesium is a silvery-white metal, malleable and ductile. It oxidizes in moist atmospheres, is volatile, and burns with a brilliant white flame at high temperatures.

Compounds. Magnesium has marked basic properties, replacing hydrogen in acids to form salts. The oxide of magnesium or "magnesia" (MgO) occurs in nature, and is also produced by the combustion of magnesium. The sulphate of magnesium or "Epsom salts" (MgSO_4) is very soluble in water, and is used in medicine. The carbonate of magnesia or "magnesia alba" (MgCO_3) is produced by the action of sodium carbonate (Na_2CO_3) upon magnesium sulphate (MgSO_4). Thus:



It is a white, light powder, insoluble in water. The hydrate of magnesium, $\text{Mg}(\text{OH})_2$, occurs free in nature, and is slightly soluble in water, and has an alkaline reaction.

STRONTIUM.

Symbol Sr. *Atomic weight* 87.6. *Equivalence* II.

Occurrence. Strontium occurs in nature as a sulphate and carbonate.

Preparation. It is prepared by electrolysis from the chloride of strontium (SrCl_2).

Properties. Strontium is a soft yellow metal. It is fusible at a red heat, and burns with a brilliant flame, forming strontium oxide (SrO).

Compounds. The native salts of strontium, the carbonate (SrCO_3) and the sulphate (SrSO_4), are insoluble in water and used principally in the preparation of the two soluble salts, the nitrate of strontium, $\text{Sr}(\text{NO}_3)_2$, and the chloride of strontium (Sr-Cl_2).

These salts are used in the arts, and in the preparation of red fire.

BARIUM.

Symbol Ba *Atomic weight* 137. *Equivalence* II.

Occurrence. Barium occurs in nature as a sulphate and carbonate.

Preparation. It is prepared from the chloride of barium (BaCl_2) by electrolysis.

Properties. It is a yellowish malleable metal, rapidly decomposing water when brought in contact with it.

Compounds. There are two oxides of barium—the barium dioxide (BaO_2), which is used in the preparation of

hydrogen dioxide (H_2O_2), and the barium oxide (BaO). The natural salts of barium are the carbonate (BaCO_3) and the sulphate (BaSO_4), both insoluble in water. The sulphate is used as a paint, and also to adulterate white lead. Both salts are used in the preparation of the soluble barium salts, the nitrate of barium, $\text{Ba}(\text{NO}_3)_2$, and the chloride (BaCl_2).

These compounds are used in making green fire.

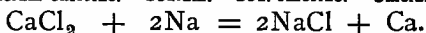
CALCIUM.

Symbol Ca. *Atomic weight* 40. *Equivalence* II.

Occurrence. Calcium is one of the most abundant elements in nature. It occurs as a carbonate in chalk, limestone, and marble; as a sulphate in gypsum; and as a phosphate, silicate, etc., in bones, minerals, and vegetables.

Preparation. It is prepared from the chloride of calcium (CaCl_2) by electrolysis or by fusing it, or the iodide of calcium (CaI_2), with sodium. Thus:

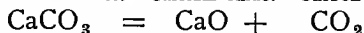
Calcium chloride. Sodium. Sod. chloride. Calcium.



Properties. Calcium is a brilliant yellow metal, malleable and ductile. It oxidizes and burns brightly at a red heat.

Compounds. One of the principal compounds of calcium is the oxide (CaO) or "lime." It is prepared by driving off carbonic oxide (CO_2) from the carbonate of calcium (CaCO_3) by means of heat. Thus:

Calcium carbonate. Calcium oxide. Carbon oxide.



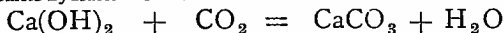
It is a hard, white solid, uniting directly with water to form calcic hydrate $\text{Ca}(\text{OH})_2$. Calcium hydrate is slightly soluble in water—the solution having an alkaline reaction, and commonly called "lime water."

Calcium sulphate (CaSO_4) or "gypsum" occurs free in nature. It contains water of crystallization, which can be driven off at a temperature of 250°C ., forming what is commonly called plaster of Paris, or cement.

It is a dry powder, but quickly hardens or sets upon the application of water.

"Mortar" is calcium hydrate, $\text{Ca}(\text{OH})_2$, and sand. Its hardening properties are chiefly due to its combination with carbonic oxide (CO_2), forming calcic carbonate (CaCO_3). Thus:

Calcic hydrate. Carbonic oxide. Calcic carbonate. Water.



The water thus produced by this combination evaporates from the walls of new buildings, making them very damp for a long time.

Barium, strontium, and calcium are called *alkaline earth metals*. These carbonates are insoluble in water, but their hydroxides are alkaline and soluble.

CHAPTER XII.

TIN, ZINC, CADMIUM.

TIN (Stannum).

Symbol Sn. *Atomic weight* 118. *Equivalence* II and IV.

Occurrence. Tin occurs principally as stannic oxide (SnO_2), called cassiterite.

Preparation. This stannic oxide is roasted and then melted with charcoal, which combines with the oxygen, leaving the metallic tin.

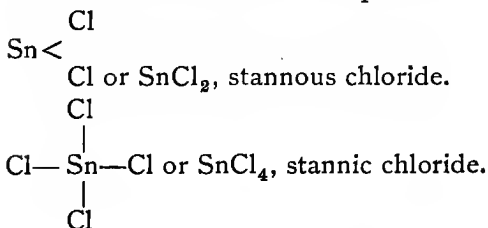
Properties. Tin is a soft white metal, very malleable and ductile. It has a peculiar odor, crackles (tin cry) when broken, and is a good conductor of heat and electricity. It is not volatile, but burns at a high temperature, forming stannic oxide (SnO_2).

Uses. Tin is used in making foil and alloys.

Compounds.

I. OF TIN AND CHLORINE.

As tin has an equivalence of two or four it forms by its union with chlorine two compounds. Thus:

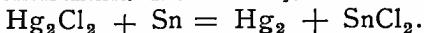


STANNOUS CHLORIDE.

Formula: SnCl_2 .

Preparation. It is prepared by the action of mercurous chloride, Hg_2Cl_2 , on tin filings. Thus:

Mercurous chloride. Tin. Mercury. Stannous chloride.



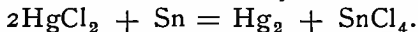
Properties. This is a grayish-white solid, soluble in water. Upon evaporating its aqueous solution, crystals, known as "tin salt," are formed, which are used in dyeing.

STANNIC CHLORIDE.

Formula: SnCl_4 .

Preparation. It is prepared by distilling mercuric chloride (HgCl_2) with tin. Thus:

Mercuric chloride. Tin. Mercury. Stannic chloride.



Properties. It is a colorless fuming liquid uniting directly with alkaline chlorides to form compounds.

It is used in dyeing.

2. OF TIN AND OXYGEN.

As there are two compounds of tin with chlorine, so two are formed by the union of tin with oxygen.

STANNOUS OXIDE.

Formula: SnO .

Properties. This oxide is a black powder which absorbs oxygen from the air, forming stannic oxide (SnO_2).

STANNIC OXIDE.

Formula: SnO_2 .

Preparation. This occurs free in nature but mixed with impurities. It is best prepared by burning tin in presence of oxygen.

Properties. Thus prepared it is a very hard white powder, insoluble in all acids save hydrofluoric (HF). It is used for polishing glass under the name of "putty powder."

By the addition of a molecule of water to each oxide two corresponding acids are formed, called stannous (H_2SnO_2) and stannic (H_2SnO_3) acids. Stannite and stannate salts are formed from the acids by substituting basic elements for the hydrogens of each.

3. OF TIN AND SULPHUR.

The principal sulphide of tin is the stannic (SnS_2). It is a golden-yellow powder known as "mosaic gold."

ZINC.

Symbol Zn. *Atomic weight* 65. *Equivalence* II.

Occurrence. It occurs in nature as zinc ore in combination with oxygen, silica, carbon, sulphur, etc.

Preparation. It is prepared by first roasting the ore and then distilling with charcoal. The oxygen is removed by combining with the carbon, and the zinc volatilizing, distils over and is condensed.

Properties. Zinc is a bluish-white, brittle metal. It is both ductile and malleable, oxidizes readily. It volatilizes and burns at high temperatures, forming zinc oxide (ZnO).

Uses. Zinc is so readily acted upon by acids that it forms the positive element in nearly all voltaic batteries.

It is also largely used in making alloys—with copper forming brass; with tin and copper, bronze, etc. Iron coated with zinc is called galvanized iron.

Compounds.

I. OF ZINC AND OXYGEN.

ZINC OXIDE.

Formula: ZnO .

Preparation. It occurs as native zinc ore, but is best prepared by the combustion of zinc in presence of oxygen.

Properties. Thus prepared, zinc oxide is a white powder, insoluble in water, and used chiefly as a pigment. By the addition of one molecule of water, zinc hydrate, $\text{Zn}(\text{OH})_2$, is formed. It has strong basic properties, and when acted upon by acids forms zinc salts, as zinc sulphate (ZnSO_4) and zinc carbonate (ZnCO_3).

2. ZINC AND CHLORINE.

ZINC CHLORIDE.

Formula: ZnCl_2 .

Preparation. Zinc chloride is prepared by dissolving zinc in hydrochloric acid (HCl), and evaporating the solution to dryness.

Properties. It is a white crystalline solid, volatile at high temperatures. It has very strong attractions for water, and hence is a powerful caustic and dehydrating agent. The sulphate and chloride are both disinfectants.

CADMIUM.

Symbol Cd. *Atomic weight* 112. *Equivalence* II.

Occurrence. It usually occurs in compounds with zinc ores as a sulphide (CdS).

Preparation. As cadmium is more volatile than zinc, it is prepared from the distillation of zinc ores, which contain it by catching the first products of distillation.

Properties. Cadmium closely resembles zinc, but is more volatile, is whiter and heavier. It is less easily attacked by acids.

Compounds :

Its compounds also closely resemble those of zinc. The sulphide (CdS) has a bright yellow color, and is used largely as a pigment.

CHAPTER XIII.

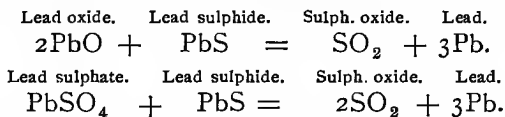
LEAD, COPPER, MERCURY.

LEAD (Plumbum).

Symbol Pb. *Atomic weight* 207. *Equivalence* II. and IV.

Occurrence. Lead occurs in nature principally as a sulphide, but also as a carbonate, arseniate, phosphate, etc.

Preparation. It is usually prepared from the sulphide (PbS) by first roasting the ore in presence of oxygen, thus forming an oxide and sulphate of lead. These compounds react upon the remaining unchanged sulphide, producing sulphurous oxide (SO₂) and metallic lead. Thus:



Properties. Lead is a soft, malleable, and bluish-white metal. It tarnishes readily in the air, and is easily fusible.

Water dissolves lead, especially if it contains organic matter or nitrates, depositing it as a carbonate (PbCO₃).

Acetic, carbonic, and nitric acids dissolve it readily, but other acids scarcely attack it. It acts as a constitutional poison when taken into the human system.

Uses. Lead is used in forming alloys—with arsenic it forms shot; with antimony and tin, type-metal; with tin, solder, etc. It is also used largely in the manufacture of water-pipes.

Compounds. Lead usually acts as a basic element with an equivalence of II., and as such replaces the hydrogens in acids to form salts. Among the most important of these salts are the sulphate (PbSO_4), the nitrate, $\text{Pb}(\text{NO}_3)_2$, the carbonate (PbCO_3), and the acetate, $\text{Pb}(\text{C}_2\text{H}_3\text{O}_2)_2$, of lead.

The plumbic acetate is soluble in water, has a sweet astringent taste, and is commonly called "sugar of lead." There are two oxides of lead: the plumbic oxide (PbO) or "litharge," which occurs free in nature, and is prepared chemically by melting lead in a current of air; and plumbic dioxide (PbO_2). Red lead is a compound of the two oxides ($2\text{PbO} + \text{PbO}_2$).

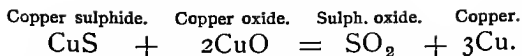
Chrome yellow is chromate of lead (PbCrO_4). Many of the lead salts are used as pigments.

COPPER (Cuprum).

Symbol Cu. *Atomic weight* 63.4. *Equivalence* II.

Occurrence. Copper occurs free in nature, but usually in combination with sulphur and iron (pyrites), carbon, oxygen, etc.

Preparation. From its combination with carbon and oxygen metallic copper is prepared by reducing the ores with carbon and silica in a blast furnace. Copper is usually prepared from the pyrites by repeatedly roasting the ore, thus converting a portion of the copper and all of the iron into an oxide. This mass is then fused with silica, forming a slag containing the iron, while the copper in the unchanged copper ore remains as a sulphide. By again roasting this sulphide the copper oxide now produced reacts upon the unchanged sulphide, forming metallic copper and sulphurous oxide. Thus:



If any of the oxide remains in the molten mass, it is reduced by "poling"—stirring with a green stick.

Properties. Copper is a reddish-colored metal, softer than iron. It is malleable, ductile, and tenacious; a good conductor of heat and electricity. It oxidizes slowly in the air at ordinary temperatures, and rapidly upon the application of heat.

It is readily dissolved by nitric acid, and slowly in weak alkaline acid, and saline solutions, forming poisonous compounds. Chlorine and sulphur attack it readily, forming chloride and sulphide of copper.

Uses. Copper is used generally in the arts, and for making alloys, as german silver, bronze, etc.

Compounds. Copper is a diad, but unites with other elements to form compounds either with the use of one or two atoms. By the use of one atom (Cu) it forms *ic* compounds, and by the use of two atoms (Cu_2), *ous* compounds. Thus there are two oxides of copper: cupric or black oxide, CuO or $\text{Cu} = \text{O}$, occurring in nature and always produced by the combustion of copper; and cuprous

or red oxide, Cu_2O , or $\begin{array}{c} \text{Cu} \\ | \\ \text{Cu} \end{array} > \text{O}$, also occurring free in nature,

and produced by the reduction of copper solutions by grape sugar in the presence of alkalies. In the same way there are two chlorides of copper, the cupric (CuCl_2) and the cuprous (Cu_2Cl_2). Both sulphides of copper (CuS and Cu_2S) occur native.

Ous and *ic* salts of copper are formed by replacing the hydrogens in acids by either Cu_2 or Cu . The *ic* salts are the most stable. Many of the copper compounds are brilliantly colored and used as pigments.

MERCURY (Hydrargyrum).

Symbol Hg. *Atomic weight* 200. *Equivalence* II.

Occurrence. Mercury occurs free in small quantities, but it is usually combined with sulphur, forming cinnabar.

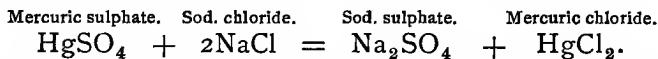
Preparation. Mercury is prepared from cinnabar by roasting the ore, thus volatilizing the metal, which is afterward condensed.

Properties. Mercury at ordinary temperatures is a silvery-white fluid metal. It freezes at -40° C., vaporizes at 15° C., and boils at 350° C. It does not oxidize at ordinary temperatures. Chlorine, sulphur, and nitric acid (HNO_3) attack it readily, but other acids do not.

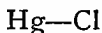
Uses. Mercury is used in the manufacture of thermometers and barometers. Its alloys are called amalgams.

Compounds. Mercury, like copper, is a diad, and unites with other elements either by the use of one or two atoms. Its compounds formed by the use of one atom (Hg) are called mercuric, while those formed by the use of two atoms (Hg_2) are called mercurous.

There are two important chlorides of mercury—the mercuric chloride HgCl_2 , and the mercurous chloride Hg_2Cl_2 . Mercuric chloride $\text{Hg} < \begin{smallmatrix} \text{Cl} \\ | \\ \text{Cl} \end{smallmatrix}$ is prepared by heating mercuric sulphate (HgSO_4) with sodium chloride (NaCl). Thus:

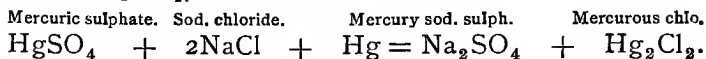


It is in the form of semi-transparent white crystals, soluble in water and very poisonous. It is commonly called bichloride of mercury, or "corrosive sublimate."



Mercurous chloride, $\begin{array}{c} | \\ \text{Hg}-\text{Cl} \end{array}$, is prepared by heating

mercury with sodium chloride (NaCl), and mercuric sulphate (HgSO_4). Thus:



This forms a heavy amorphous powder, insoluble in water and not very poisonous. It is commonly called "calomel."

By heat and exposure to light it decomposes into mercury and mercuric chloride (HgCl_2).

There are also two important iodides of mercury, the mercuric iodide (HgI_2), and the mercurous iodide (Hg_2I_2).

Ous and *ic* salts of mercury are formed by replacing the hydrogens of acids with Hg_2 or Hg .

Thus $\text{Hg}(\text{NO}_3)_2$ is mercuric nitrate, and $\text{Hg}_2(\text{NO}_3)_2$ is mercurous nitrate.

The *ic* compounds of mercury are more stable than the *ous*. "White precipitate," so called, is a mercury amide, HgClNH_2 or $(\text{NH}_2)\text{—Hg—Cl}$.

"Turpeth mineral" ($\text{HgSO}_4 + 2\text{HgO}$) is an emetic and used in medicine.

CHAPTER XIV.

PLATINUM, GOLD, SILVER.

PLATINUM.

Symbol Pt. *Atomic weight* 194.4. *Equivalence* II and IV.

Occurrence. Platinum occurs native in round grains, but is usually impure, containing gold, iron, copper, etc.

Preparation. It is best prepared by melting the impure platinum with lead, which forms a nearly pure alloy of platinic lead. This alloy is next heated in a current of air. The lead melts, oxidizes, and is drawn off as slag, leaving the pure platinum as a porous mass.

Properties. Platinum is a white, very malleable, and ductile metal; a good conductor of heat and electricity and only fusible in an oxy-hydrogen blow-pipe flame. It is not attacked by single acids, and is but slowly dissolved in aqua-regia.

It does not tarnish. Finely divided or in the porous form, platinum will absorb 800 times its own volume of oxygen, and thus is an active oxidizing agent.

Compounds. As platinum has an equivalence of II or IV, its compounds are either *ous* or *ic*. Thus there are *two* chlorides of platinum—the platinous chloride (PtCl_2), and the platinic chloride (PtCl_4), which is formed by dissolving platinum in aqua-regia.

GOLD (Aurum).

Symbol Au. *Atomic weight* 197. *Equivalence* I and III.

Occurrence. Gold is found pure in nature in quartz rock or sand.

Preparation. The quartz rock containing the gold is finely pulverized and treated with mercury, which forms an amalgam with the gold. The mercury is distilled off, leaving the pure gold.

Properties. Gold is a soft yellow metal, very ductile and malleable; does not tarnish in the air, and the only acid attacking it is aqua-regia.

Uses. It is used in forming alloys and for coinage and jewelry.

Compounds. Gold having an equivalence of I or III, forms *ous* and *ic* compounds, the most important of which are the chlorides, AuCl and AuCl_3 .

Auric chloride (AuCl_3) is produced by dissolving gold in aqua-regia.

The two oxides of gold are aurous oxide (Au_2O) and auric oxide (Au_2O_3).

SILVER (Argentum).

Symbol Ag. *Atomic weight* 108. *Equivalence* I and III.

Occurrence. Silver is found free in nature and in combination with sulphur, bromine, chlorine, etc.

Preparation. Silver is often found in combination with lead, and is extracted from it in a manner analogous to that of separating gold from its amalgam with lead. Silver is prepared from its sulphide by roasting the ore with sodium chloride, thus forming chloride of silver. The mass is then ground fine, and agitated with water and scrap iron, which reduces the silver to the metallic state. Mercury is then added, which takes up the silver and is afterward distilled off, leaving the pure metal.

Properties. Silver is a white metal, ductile, malleable, tenacious, and harder than gold. It is the best conductor of heat and electricity known. Does not tarnish in air, but is easily attacked by chlorine, sulphur, nitric acid, etc.

Uses. Silver is used for coinage, and also in making jewelry and alloys.

Compounds. Silver usually acts as a monad. It has strong basic properties, replacing the hydrogens in acids to form salts. Thus we have nitrate of silver, AgNO_3 , sulphate of silver, Ag_2SO_4 , chloride of silver, AgCl , and are chemically all produced by dissolving silver in the corresponding acid, viz.: nitric acid (HNO_3), sulphuric acid (H_2SO_4), and hydrochloric acid (HCl).

Many of the salts of silver, especially the nitrate, turn black in presence of sunlight or organic matter, and therefore are used in photography and for hair dyes, indelible inks, etc.

CHAPTER XV.

CHROMIUM, MANGANESE, ALUMINUM.

CHROMIUM.

Symbol Cr. *Atomic weight* 52.5. *Equivalence* II and $(Cr_2)VI$.

History. This metal received the name of chromium from the beautiful color of most of its compounds.

Occurrence. It occurs in nature combined with oxygen, iron, and lead.

Preparation. It is prepared by heating the ore with charcoal, and thus reducing the oxide.

Properties. It is a steel-gray, infusible, and extremely hard metal.

Burned in oxygen it forms chromic oxide (Cr_2O_3).

Compounds. As chromium has an equivalence of II or VI it forms *ous* and *ic* compounds by its union with chlorine, oxygen, etc,

But beside one atom of chromium uniting with other atoms to form compounds, two atoms with an equivalence of VI also unite with the same kind of atoms to form different compounds. Thus there are two chromic oxides: CrO_3 , called chromic tri-oxide, and Cr_2O_3 , chromic oxide.

CHROMIC TRI-OXIDE.

Formula: CrO_3 .

Properties. This oxide exists as crimson, needle-shaped crystals.

It is very deliquescent and a powerful oxidizing agent. By the addition of a molecule of water chromic acid (H_2CrO_4) is formed.

CHROMIC ACID.

Formula: H_2CrO_4 .

Properties. Chromic acid is a pinkish and corrosive fluid.

By its evaporation it loses water, and crystals of chromic tri-oxide CrO_3 . are formed.

Chromate salts are formed by replacing the hydrogens in chromic acid by basic elements as sodium and potassium, thus forming sodium chromate (Na_2CrO_4) and potassium chromate (K_2CrO_4).

Bichromate salts, the most important of which is potassium bichromate ($\text{K}_2\text{Cr}_2\text{O}_7$), are formed by replacing the hydrogens in bichromic acid ($\text{H}_2\text{Cr}_2\text{O}_7$) with basic elements. This bichromic acid is theoretically formed by adding a molecule of water to a double molecule of chromic oxide, $2(\text{CrO}_3)$.

CHROMIC OXIDE.

Formula: Cr_2O_3 .

Properties. As usually prepared, chromic oxide is an amorphous, green powder. It is very hard and insoluble in acids. It is used principally as an indelible ink for coloring bank-notes green. Theoretically, there is formed a second chromic acid ($\text{H}_2\text{Cr}_2\text{O}_4$) by the addition of water to the oxide.

The salts formed from this acid by substituting basic elements for the hydrogen are called chromites. Thus there is ferrous chromite (FeCr_2O_4).

Chromium sometimes acts as a basic element, and will

replace the hydrogen atoms in acids to form salts, as sulphate of chromium, $\text{Cr}_2(\text{SO}_4)_3$.

MANGANESE.

Symbol Mn. *Atomic weight* 55. *Equivalence* II–IV–VI.

History. Manganese received its name from having at first been mistaken for magnetic iron.

Occurrence. It occurs usually in nature as an oxide, but also in combination with sulphur, iron, and arsenic.

Preparation. It is prepared by reduction of its oxide (MnO_2) with charcoal at a high temperature.

Properties. It is a grayish-white brittle metal, oxidizing readily, forming manganese dioxide (MnO_2).

Compounds. As manganese usually has an equivalence of II or VI, by its union with chlorine, oxygen, etc., are formed *ous* and *ic* compounds.

With an equivalence of VI, manganese may unite with other elements either by the use of one or two atoms. Thus manganic trioxide is MnO_3 , and manganic oxide is Mn_2O_3 .

There is still a third oxide of manganese, which is the one occurring in nature and called manganic dioxide (MnO_2). Manganese in this compound has an equivalence of IV.

Manganic dioxide gives off oxygen readily upon application of heat, and hence is a good oxidizing agent. Theoretically acids and salts are produced from these oxides in a manner analogous to the formation of similar acids and salts from chromium oxides. But besides the *ate* and *ite* salts thus produced, there are also *permanganates* formed by substituting basic elements in place of the hydrogen in *permanganic acid* ($\text{H}_2\text{Mn}_2\text{O}_8$).

The most important of these salts is potassium perman-

ganate ($K_2Mn_2O_8$) which is a strongly oxidizing agent, and therefore extensively used as a disinfectant.

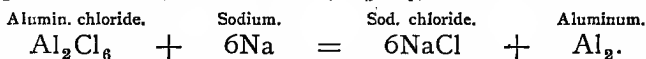
Preparation. Manganese acting as a basic element with an equivalence of II will replace the hydrogens in acids, forming salts, as, for example, sulphate of manganese ($MnSO_4$).

ALUMINUM.

Symbol Al. *Atomic weight* 27.5. *Equivalence* (Al_2) VI.

Occurrence. Aluminum is the most abundant element in nature next to oxygen and silicon, with which it is usually found combined. The ruby and sapphire are oxides of aluminum. Clay is a silicate of aluminum.

Preparation. Aluminum is prepared by passing the vapor of aluminum chloride (Al_2Cl_6) over sodium. Thus:



Properties. It is a very light bluish-white metal, malleable and ductile. It is not volatile, but will burn at a high temperature, forming aluminum oxide (Al_2O_3). It does not tarnish easily.

Uses. Aluminum is made into ornaments and used in forming alloys. With sand and limestone it forms porcelain.

Compounds. Aluminum has strong basic properties, and unites by use of two atoms (Al_2) with acids to form salts. The sulphates $Al_2(SO_4)_3$ are the most important compounds, as they are characteristic ingredients of all alums.

An alum is a double sulphate plus water, and may be expressed by the general formula $Al_2(SO_4)_3 + (x) + H_2O$. The potash alum, $Al_2(SO_4)_3 + K_2SO_4 + 24(H_2O)$, is the most common. All alums are crystalline and styptic, used principally in dyeing.

CHAPTER XVI.

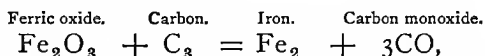
IRON, COBALT, NICKEL.

IRON (Ferrum).

Symbol Fe. *Atomic weight* 56. *Equivalence* II and (Fe₂) VI.

Occurrence. Pure iron occurs very sparingly in nature, but in combination with oxygen (Fe₂O₃ and Fe₃O₄), silicon, sulphur, carbon, etc., it is abundant.

Preparation. Iron is usually prepared by heating to a high temperature alternate layers of iron ore (ferric oxide, Fe₂O₃), charcoal, and limestone. The carbon removes the oxygen. Thus:



while the limestone unites with the silica and other impurities to form a fusible silicate, which collecting above the melted iron can be drawn off in form of "slag."

Properties. Iron thus prepared is run into molds, and hence called "cast" or "pig" iron.

This is not pure iron but contains carbon, manganese, sulphur, and other impurities. White pig-iron contains more carbon than does the gray, and is therefore whiter in color, harder, more brittle, and more fusible than the gray. "Wrought" iron differs from pig-iron by being comparatively pure. It is prepared from pig-iron by burning out all its impurities by a process of oxidation called "puddling." Wrought iron is bluish-gray in color, fibrous in structure, and malleable.

"Steel" is a form of iron containing from 2 to 4 per cent. carbon, and is prepared by heating wrought iron to redness with charcoal.

Bessemer steel is a variety of iron containing beside the carbon, manganese. It is prepared by melting spiegeleisen (pig-iron containing manganese and carbon) with wrought iron.

Steel resembles wrought iron, but is granular in structure and more malleable and fusible. It also has the peculiar property of becoming very hard and brittle when heated and then suddenly cooled.

Compounds. As iron usually has an equivalence of II or VI, by its union with other elements *ous* and *ic* compounds are formed. In the *ic* compounds, however, iron usually unites with other elements by the use of two atoms (Fe_2 with an equivalence of VI) instead of one. Thus ferric carbonate is $\text{Fe}_2(\text{CO}_3)_3$.

OF OXYGEN AND IRON.

There are three oxides of iron—ferrous oxide (FeO), ferric oxide (Fe_2O_3), and magnetic oxide (Fe_3O_4).

The ferric oxide is found in large quantities in nature, and the magnetic oxide or loadstone, so named from its magnetic properties, in small quantities.

COBALT.

Symbol Co. *Atomic weight* 59. *Equivalence* II and VI.

Occurrence. It occurs free in meteorites, but is usually found in combination with arsenic.

Preparation. It is prepared by roasting the ore, thus driving off the arsenic, which is volatile. The other elements with which it is found are gotten rid of chemically, leaving the oxide of cobalt (Co_2O_3), which is reduced by heating with charcoal, thus leaving the pure cobalt.

Properties. It has a steel-gray color, is magnetic, very hard, oxidizes at a red heat and tarnishes readily in a moist atmosphere.

Compounds. Most of the cobalt compounds have brilliant colors, and hence are used as pigments. As cobalt has usually an equivalence of II or VI it forms *ous* and *ic* compounds—the *ous* salts being the more important. In most of the *ic* compounds cobalt unites with other elements by the use of two atoms (Co_2). It has strong basic properties replacing the hydrogens in acids.

OF COBALT AND OXYGEN.

There are three oxides of cobalt analogous to those of iron—cobaltous oxide (CoO), cobaltic tri- or sesqui-oxide (Co_2O_3), and cobaltic oxide (Co_3O_4).

NICKEL.

Symbol Ni. *Atomic weight* 59. *Equivalence* II–IV–VI.

Occurrence. It occurs free in meteoric iron ore, but is found usually in combination with arsenic, antimony, and sulphur.

Preparation. It is prepared in a manner analogous to the preparation of cobalt.

Properties. Nickel is a silver-white metal, ductile and malleable. It does not tarnish in dry air, and is not easily attacked by acids.

Uses. Nickel is used for plating and in making alloys. German silver is an alloy of nickel, copper, and zinc.

Compounds. The equivalence, mode of union and compounds of nickel are analogous to those of cobalt. The *ous* salts are more important than the *ic*; the nitrate, $\text{Ni}(\text{NO}_3)_2$, and sulphate (NiSO_4) are the two most important soluble nickel salts.

CHAPTER XVII.

ARSENIC.

Symbol As. *Atomic weight* 75. *Equivalence* III-V.

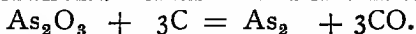
History. Pure arsenic was first obtained by Schroeder, in 1694. It had been known in combination for centuries.

Occurrence. Arsenic occurs free as native arsenic, but usually in combination with iron, cobalt, nickel, and sulphur.

Preparation. It is prepared by roasting arsenic ore, thus driving off the volatile arsenic, which is condensed as arsenious oxide, As_2O_3 .

This oxide is then reduced by heating it with charcoal. Thus:

Arsenious oxide. Carbon. Arsenic. Carbon monoxide.



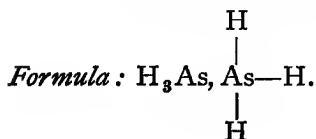
Properties. Arsenic is a brittle solid with a metallic lustre. It is volatilized by heat, giving off yellowish fumes with a garlic-like odor.

At a high temperature arsenic burns with a blue flame forming arsenious oxide (As_2O_3).

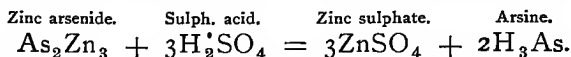
Compounds.

I. OF ARSENIC AND HYDROGEN.

HYDROGEN ARSENIDE OR ARSINE.



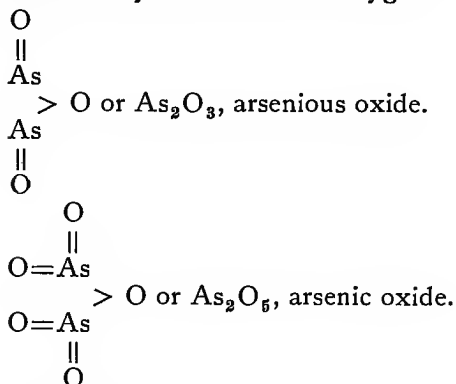
Preparation. Arsenic is prepared by the action of sulphuric acid (H_2SO_4) upon zinc arsenide (As_2Zn_3). Thus:



Properties. Arsine is a colorless gas with a garlic-like odor. It is soluble in water and combustible, forming by its combustion arsenious oxide (As_2O_3).

2. OF ARSENIC AND OXYGEN.

As arsenic has an equivalence of III or V, two oxides are formed by its union with oxygen. Thus:



From these oxides by the addition of 3 molecules of water, two acids are formed:

$\text{As}_2\text{O}_3 + 3\text{H}_2\text{O} = 2\text{H}_3\text{AsO}_3$, arsenious or ortho arsenious acid; and

$\text{As}_2\text{O}_5 + 3\text{H}_2\text{O} = 2\text{H}_3\text{AsO}_4$, arsenic acid.

ARSENIOUS OXIDE.

Formula, As_2O_3 .

Synonym, arsenious acid.

Occurrence. It occurs free in nature under the name of arsenolite.

Preparation. It is prepared by roasting arsenic ores in an access of air, and condensing the vapor formed.

Properties. Arsenious oxide exists in two forms, crystalline and vitreous. The form taken by the oxide seems to depend upon the amount of heat the vapor has been subjected to in condensing: if less than $250^{\circ}\text{C}.$, the octahedral or rhomboid crystals are formed; if more than that, the vitreous variety.

The crystalline form by exposure to the air at ordinary temperatures slowly changes to the vitreous variety.

Both forms are soluble in alkaline solutions, hydrochloric acid (HCl), and slightly in water. From its solution it crystallizes in octahedral crystals.

ARSENIOUS ACID.

Formula, H_3AsO_3 .

Preparation. It is obtainable by dissolving arsenious acid in water.

Properties. Arsenious acid is a styptic liquid, with an acid reaction, not very stable.

Arsenite salts are formed by substituting for the hydrogen in the acid, basic elements. These salts are not easily decomposed. Among the most important of them are potassium arsenite (K_3AsO_3), which is the principal ingredient in *Fowler's solution* of arsenic, *Scheele's green*, and other pigments.

Paris green is a double salt of arsenite and acetate of copper.

ARSENIC OXIDE.

Formula, As_2O_5 .

Preparation. This is prepared by heating arsenious oxide (As_2O_3) with nitric acid (HNO_3), evaporating the solution to dryness, and heating to $270^{\circ}\text{C}.$

Properties. It is an opaque, white, amorphous solid, and is decomposed by heat. By the addition of water *arsenic acid* (H_3AsO_4) is formed.

Arsenic salts are formed from the acid by substituting for the hydrogen basic elements.

All forms of arsenic are poisonous, especially the *ite* salts.

Tests for arsenic.

a. *Sublimation test :*

Heat arsenic in a glass tube with air. Crystals of arsenious oxide, (As_2O_3) will be deposited on the glass.

b. *Reduction test :*

Heat arsenic in a closed tube with charcoal. A metallic mirror of arsenic will form on sides of tube.

c. *Sulphuretted hydrogen test :*

Pass sulphuretted hydrogen (H_2S) through a hydrochloric acid (HCl) solution of arsenic. A lemon-yellow precipitate will form, which is soluble in ammonia.

d. *Sulphate of copper test :*

Add to an ammoniacal solution of arsenic, a solution of sulphate of copper (CuSO_4). A green precipitate is produced, which is soluble in access of ammonia.

e. *Marsh's test :*

Add a solution of arsenic to sulphuric acid (H_2SO_4), and then add metallic zinc. Collect the gas given off, which will contain hydrogen arsenide. This gas will have the properties of hydrogen arsenide. If the gas is ignited and the flame directed against a piece of cold porcelain, a black stain will remain which is soluble in hyposulphite of soda (Na_2SO_3).

CHAPTER XVIII.

ANTIMONY AND BISMUTH.

ANTIMONY (stibium).

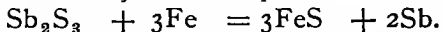
Symbol Sb. *Atomic weight* 122. *Equivalence* III and V.

History. Pure antimony was obtained by Valentine, in 1492.

Occurrence. It occurs in nature, both free and combined with oxygen, sulphur, silver, etc.

Preparation. It is prepared by melting sulphide of antimony (Sb_2S_3) with iron. Thus:

Sulphide of antimony. Iron. Sulph. of iron. Antimony.



Or by roasting antimony ore, thus obtaining the oxide (Sb_2O_3), which is reduced by heating with charcoal, analogous to the preparation of arsenic.

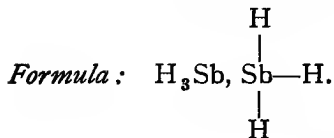
Properties. Antimony is a bluish-white, brittle metal not easily tarnished. It fuses and burns at elevated temperatures; producing by its combustion antimonous oxide (Sb_2O_3).

Uses. Antimony is used largely in making type-metal.

Compounds:

I. OF ANTIMONY AND ^{Hydrogen}~~OXYGEN~~.

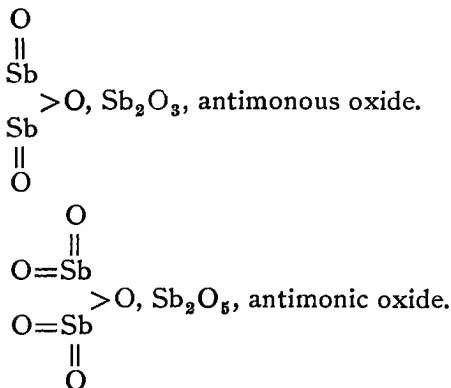
HYDROGEN ANTIMONIDE.



Preparation and properties. It is prepared in a manner analogous to that of hydrogen arsenide (AsH_3), and has properties very similar to that compound. Its stain on porcelain, however, is darker and not soluble in hyposulphite of soda ($\text{Na}_2\text{S}_2\text{O}_3$).

2. OF ANTIMONY AND OXYGEN.

As antimony has an equivalence of III and V, by its union with oxygen two oxides are formed. Thus:



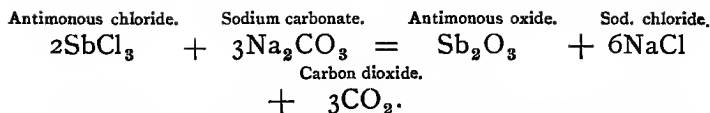
And from these oxides, as in arsenic, *ous* and *ic* acids are formed. Chemically, the oxides, acids, and salts of antimony resemble those of arsenic. The principal oxide of antimony is the *ous* oxide.

ANTIMONOUS OXIDE.

Formula, Sb_2O_3 .

Occurrence. This oxide occurs free in nature.

Preparation. It may be prepared by boiling antimonous chloride (SbCl_3) with a solution of sodium carbonate (Na_2CO_3).



Properties. It is a dirty-white powder, slightly soluble in water, forming the *ous* acid.

Salts corresponding to this acid are used in medicine. Tartar emetic (2KSbO , $\text{C}_4\text{H}_4\text{O}_6$) is a double salt of potassium antimony tartrate.

3. ANTIMONY AND SULPHUR.

There are two sulphides of antimony, the *ous* (Sb_2S_3) and *ic* (Sb_2S_5). The former is found free in nature.

BISMUTH.

Symbol Bi. *Atomic weight* 210. *Equivalence* III and V.

History. It was discovered pure by Valentine in 1492.

Occurrence. Bismuth occurs free in nature, but usually in combination with oxygen or sulphur.

Preparation. It is prepared by reducing the sulphide of bismuth (Bi_2S_3) with charcoal at a high temperature.

Properties. Bismuth is a hard, brittle, reddish-white metal, remaining untarnished in dry air. At high temperatures it melts and burns with a white flame, forming by its combustion bismuthous oxide (Bi_2O_3).

Uses. Bismuth is used principally in forming alloys.

Compounds:

I. OF BISMUTH AND OXYGEN.

As bismuth has an equivalence of III and V, by its union with oxygen two oxides are formed, the *ous* (Bi_2O_3) and *ic* (Bi_2O_5), and from them the corresponding acids and salts.

2. OF BISMUTH AND CHLORINE.

Chlorine being a monad, unites with bismuth to form two compounds,—bismuthous chloride (Bi Cl_3) and bismuthic chloride (Bi Cl_5). In the same way are formed two compounds of bismuth and sulphur,—the *ous* (Bi_2S_3), which occurs free in nature, and the *ic* (Bi_2S_5).

Nitrate of bismuth, $\text{Bi}(\text{NO}_3)_3$; the subnitrate, $\text{O}=\text{Bi}-\text{NO}_3$; the carbonate, $\text{Bi}_2(\text{CO}_3)_3$; and subcarbonate, $(\text{BiO})_2\text{CO}_3$; are some of the salts of bismuth used in medicine.

PART IV.
ORGANIC CHEMISTRY.

ORGANIC CHEMISTRY.

CHAPTER I.

Organic chemistry treats of the chemistry of the chemistry of the carbon compounds.

The peculiarities of these compounds are, first, their extraordinary number; second, the few elements that enter into their composition, nearly all of them being formed by the union of carbon with hydrogen, nitrogen, and oxygen; and lastly, the large number of atoms contained in each molecule.

The cause of the multiplicity of these organic compounds is found in the peculiarity which carbon itself possesses of uniting with itself and other elements, especially nitrogen, oxygen, and hydrogen, to form chemical combinations.

Thus, for example, carbon being a tetrad, it has four bonds to be satisfied by union with other bonds. If no free bonds remain the compound is called *saturated*; if otherwise, *unsaturated*. Not only may these free bonds become saturated by union with simple elements, but also with radicals, both simple and compound, thus greatly increasing the complexity of composition as well as the number of organic compounds.

Compounds are said to be *isomeric* when they have the same percentage composition, but differ in their physical properties.

They are *metameric* when they have the same percentage composition and molecular weight, but differ in their chemical properties and transformations.

They are *polymeric* when they have the same percentage composition, but differ in molecular weight.

Proximate analysis is the analysis of a mixture by which we ascertain the definite chemical compounds which exist in it.

Ultimate analysis is that determining the percentage of the elements in any chemical compound.

Organic compounds form an *homologous series* when their general formulæ differ from one another by CH_2 , viz., by the replacement of a hydrogen by CH_3 . Thus the hydrocarbon series (CH_4) are homologous, as each formula differs from the preceding one by CH_2 , and this series can therefore be expressed by the general formula, $\text{C}_n\text{H}_{2n+2}$ (n representing the number of atoms taken of each element to form the molecule).

Organic chemistry may be divided into two great divisions, called the *fatty* and *aromatic groups*, the fatty group being derived from methane (CH_4) and the aromatic group from benzene (C_6H_6).

For formation of *acids, alcohols, aldehydes, ethers, and compound ethers*, see page 216.

CHAPTER II.

FATTY GROUP.

HYDROCARBONS.

Compounds consisting of only carbon and hydrogen are called *hydrocarbons*. They form a number of interesting series, the compounds of each series differing from one another by CH_2 . These series start from the saturated compound methane (CH_4), and from which is derived the following homologous series, viz.: By the addition of CH_2 , CH_4 , C_2H_6 , C_3H_8 , C_4H_{10} , C_5H_{12} , etc., and can be represented by the general formula

$\text{C}_n\text{H}_{2n+2}$, called the *paraffin series*.

All of these homologous series represent saturated compounds, but by taking away from each formula one molecule or two atoms of hydrogen we have formed a number of homologous series, whose general terms are expressed thus: C_nH_{2n} , $\text{C}_n\text{H}_{2n-2}$, $\text{C}_n\text{H}_{2n-4}$, $\text{C}_n\text{H}_{2n-6}$, etc., and whose compounds are unsaturated. These series are represented in the following table:

Paraffin series.	Olefine series.	Acetyline series, etc.		
$\text{C}_n\text{H}_{2n+2}$	C_nH_{2n}	$\text{C}_n\text{H}_{2n-2}$	$\text{C}_n\text{H}_{2n-4}$	$\text{C}_n\text{H}_{2n-6}$
Methane.	Methene.			
CH_4 ,	CH_2 ,			
Ethane.	Ethene.	Ethine.		
C_2H_6 ,	C_2H_4 ,	C_2H_2 ,		
Propane.	Propene.	Propine.	Propone.	
C_3H_8 ,	C_3H_6 ,	C_3H_4 ,	C_3H_2	

Butane. C_4H_{10} ,	Butene. C_4H_8 ,	Butine. C_4H_6 ,	Butone. C_4H_4 ,	Butune. C_4H_2 , etc.
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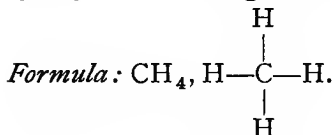
The name of each compound ends in *ne* with the prefix *a*, *e*, *i*, *o*, or *u*, in order in each series, starting with *a* for the highest series (C_nH_{2n+2}).

CHAPTER III.

METHANE COMPOUNDS AND DERIVATIVES.

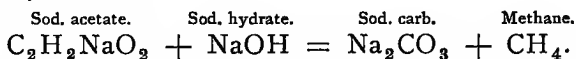
METHANE.

Synonyms : Marsh gas ; fire damp.



Occurrence. Methane occurs free in marshes and coal mines, and is the product of the slow decomposition of organic substances in the absence of oxygen.

Preparation. It is best prepared chemically by heating sodium acetate ($\text{C}_2\text{H}_3\text{NaO}_2$) with sodium hydrate (NaOH). Thus:



Properties. Methane is a colorless, odorless gas, easily combustible, and burning with a blue flame. It forms an explosive compound when mixed with air or oxygen.

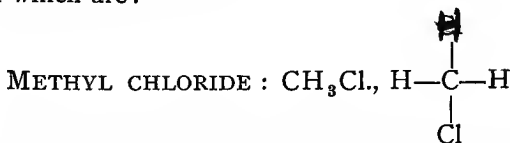
Use. It forms an important constituent of illuminating gas.

Compounds of Methane :

HALOGEN SUBSTITUTIONS.

By substituting halogen elements for one or more hydrogen atoms in methane we obtain a series of com-

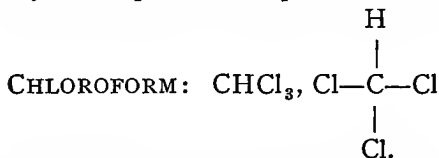
pounds called *Haloid ethers*, among the most important of which are:



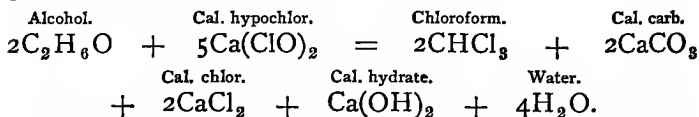
This compound does not occur free in nature, but is produced by the action of hydrochloric acid (HCl) upon methyl alcohol (CH₄O). It is a colorless gas with a sweetish taste.

METHYL BROMIDE, CH₃Br. This compound is prepared by the action of hydrobromic acid (HBr) on methyl alcohol (CH₄O). It is a colorless liquid with an ether-like odor.

METHYL IODIDE, CH₃I. This is prepared like the above by the action of hydroiodic acid (HI), upon methyl alcohol (CH₄O). It forms a colorless liquid, which is easily decomposed on exposure to the light.



Chloroform is best prepared by the action of calcium hypochlorite Ca(ClO)₂ on common alcohol (C₂H₆O). The process is a complicated one, but can be expressed in a general way by the following formula:



It is a colorless liquid with a pleasant odor, but slightly combustible, burning with a green flame.

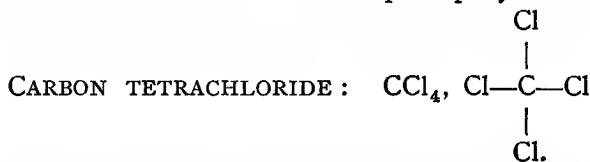
It is soluble in alcohol and ether, but slightly soluble in water. When perfectly pure it sinks readily in water without causing a troubling, and will not redden litmus paper.

It is used principally as a solvent and an anæsthetic.

BROMOFORM, CHBr_3 . This is a colorless liquid with an odor like chloroform.

IODIFORM, CHI_3 . Iodiform is best prepared by the action of iodine on a solution of sodium carbonate (Na_2CO_3) in alcohol ($\text{C}_2\text{H}_5\text{O}$).

Thus prepared it is a yellowish crystalline flaky solid with saffron-like odor. It is insoluble in water, but soluble in alcohol and ether. It is used principally in medicine.



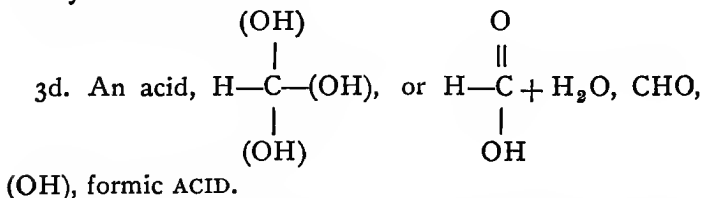
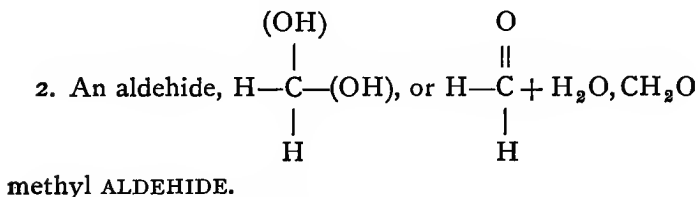
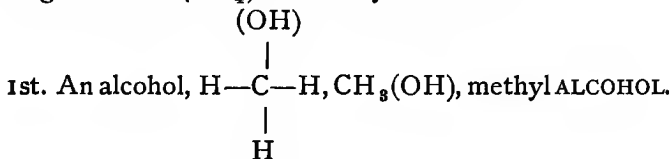
This compound is usually prepared from chloroform, and is a colorless liquid with a pleasant odor.

CHAPTER IV.

HYDROXYL SUBSTITUTION.

By substituting hydroxyl (OH) for one hydrogen in a hydrocarbon, an *alcohol* is produced, for two hydrogens an *aldehyde*, and for three hydrogens an organic *acid*.

These substitutions can be represented as follows, taking methane (CH_4) as the hydrocarbon:



COMPOUND ETHERS or ESTERS are formed from *acids* by substituting for the hydroxyl hydrogen of the acid, hydrocarbon radicals or alcohol rests (alcohol minus hy-

droxyl). Thus by substituting for the hydroxyl hydrogen of formic acid $\text{CHO}(\text{OH})$, methyl (CH_3), there is formed methyl formic ether, $\text{CH}_3, \text{CHO}_2$.

Compound ethers are formed from *alcohol* by replacing the hydroxyl hydrogen of the alcohol by acid rests (acid minus hydroxyl).

ETHERS are formed from alcohols by heating them with sulphuric acid (H_2SO_4), and consist simply of two hydrocarbon radicals, as methyl (CH_3) united by oxygen. Thus: $\text{CH}_3\text{—O—CH}_3$ is methyl ether.

Having now considered the formation of alcohols, acids, etc., we come to the study of those connected with the methane compounds.

METHYL ALCOHOL, CH_3OH .

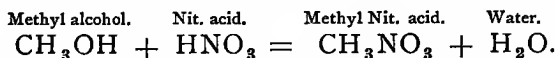
Synonyms. Carbonal, wood spirits.

Preparation. It is obtained with crude acetic acid in the distillation of wood.

Properties. Methyl alcohol is a colorless mobile liquid with the odor and taste of common alcohol. It is combustible and has remarkable dissolving properties, readily dissolving essential oils, varnishes, etc.

Uses. It is used principally in the manufacture of aniline dyes and as a solvent. Alcohols unite with acids to form *compound ethers* or *esters*, a molecule of water being given off.

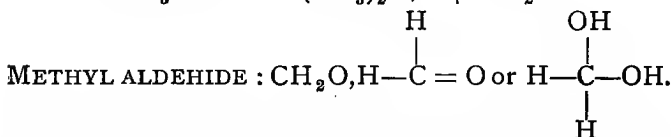
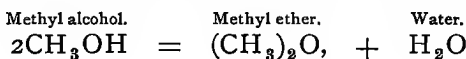
Thus methyl alcohol (CH_3OH) with nitric acid (HNO_3) forms *methyl nitric acid* or *ether* (CH_3NO_3) and water.



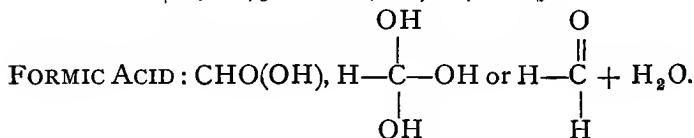
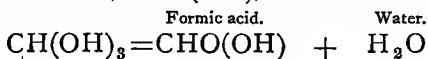
These esters are formed by simply replacing the hydroxyl hydrogen of alcohol with an acid rest (acid minus hydroxyl). Thus methyl alcohol with sulphuric acid (H_2SO_4) forms *methyl sulphuric acid* ($\text{CH}_3\text{O}, \text{HSO}_3$) or

(CH_3 , HSO_4), with phosphoric acid (H_3PO_4) *methyl phosphoric acid* (CH_3 , H_2PO_4). If there remains a replaceable hydrogen in any of these esters, viz., a hydrogen in the acid rest as in the methyl sulphuric and phosphoric esters, —the compounds are called acids or ester acids, and the hydrogens are replaceable with metallic elements as sodium and potassium, forming *organic salts*. Thus *methyl sodium sulphate* has the formula CH_3 , NaSO_4 .

METHYL ETHER: (CH_3) $_2\text{O}$, or $\text{CH}_3\text{—O—CH}_3$ is obtained by heating methyl alcohol (CH_3OH) with sulphuric acid, the alcohol being split up into ether and water thus:

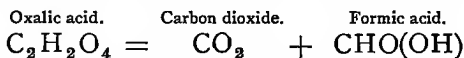


Preparation. Methyl aldehyde is prepared by passing the vapor of methyl alcohol (CH_3OH), mixed with air, over a heated platinum spiral. If the oxidation is effected with stronger agents, as sulphuric acid (H_2SO_4) and manganese dioxide (MnO_2), three hydrogens are replaced by OH, and formic acid, $\text{CHO}(\text{OH})$, and water are produced:

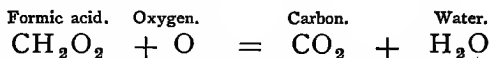


Occurrence. It exists in nature in ants, pine needles, urine, and blood. It also is a product of the decomposition of sugar, starch, gums, etc.

Preparation. Formic acid is best prepared by the decomposition of oxalic acid ($C_2H_2O_4$) in glycerine, as thus presented:



Properties. It is a colorless acid liquid soluble in water and alcohol. Its vapor is combustible. It is a good reducing agent, uniting with oxygen to form carbonic dioxide (CO_2) and water. Thus:



Salts of this acid can be formed by replacing one hydrogen (the hydrogen of the hydroxyl OH) by a metallic element, as sodium, etc. Thus: *sodium formate* has the formula CHO , NaO or CHO_2 , Na ; *lead formate*, $(CHO_2)_2Pb$, etc.

CHAPTER V.

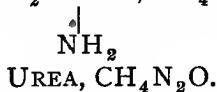
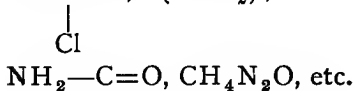
OXYGEN SUBSTITUTIONS.

Oxygen may be substituted for the hydrogen in methane, but as oxygen is a diad it will take two hydrogens to satisfy one oxygen.

CARBONYL: CO , $>\text{C} = \text{O}$.

Synonym: Carbon monoxide.

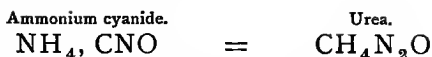
Carbonyl is a compound radical with an equivalence of two, and has been already treated of under inorganic chemistry. From it organic compounds are formed by saturating its free bonds with other elements or compound radicals. Thus with sulphur it forms *carbonyl sulphide* ($\text{S} = \text{C} = \text{O}$); with chlorine, *carbonyl chloride*, $\text{Cl}-\text{C}=\text{O}$, (COCl_2); with amodogen (NH_2), *urea*,



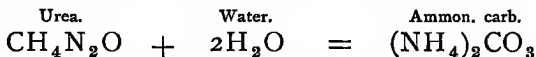
Synonym. Carbamide.

Occurrence. Urea is found in the urine of all mammals and in small amount in many animal juices. It is the product of the oxidation of the nitrogenous elements of the body.

Preparation. It is best prepared by the decomposition of ammonium cyanide (NH_4, CNO) by heat, as represented in the following equation:



Properties. Urea crystallizes in four-sided prisms and is soluble in water and alcohol. It has a bitter, cooling taste like saltpetre, and is readily decomposed by heat, setting free ammonia. Boiling with water, alkalies, or acids the following decomposition takes place :



This decomposition also takes place spontaneously in urine, causing its alkaline fermentation.

Compounds. Urea combines with acids to form salts. Thus with nitric acid (HNO_3) it forms *nitrate of urea* ($\text{CH}_4\text{N}_2\text{O}, \text{HNO}_3$), which is but slightly soluble in water ; hence urea can be readily separated from its solution by first converting it into the nitrate by the addition of nitric acid.

Compound ureas are formed by replacing one or more of the hydrogens in urea with hydrocarbon radicals, as methyl (CH_3), ethyl (C_2H_5), etc., thus forming *methyl urea* ($\text{CH}_3\text{N}_2\text{O}, \text{CH}_3$), *ethyl urea* ($\text{CH}_3\text{N}_2\text{O}, \text{C}_2\text{H}_5$), etc.

CARBON DIOXIDE: $\text{CO}_2, \text{O} = \text{C} = \text{O}$.

This compound has been already studied in inorganic chemistry.

CHAPTER VI.

SULPHUR SUBSTITUTIONS.

As oxygen may take the place of hydrogens in methane, in like manner sulphur may be substituted. If sulphur be substituted for one hydrogen, sulphur being a diad, *methyl sulphide*, $(\text{CH}_3)_2\text{S}$, is produced; for two hydrogens, *methyl sulphal-dehide* (CH_2S), etc.

The most important compound of this group thus produced is carbon bi-sulphide, CS_2 , all the hydrogens being replaced.

CARBON BI-SULPHIDE: CS_2 , $\text{S} = \text{C} = \text{S}$.

Preparation. Carbon bi-sulphide is best prepared by passing sulphur vapor over glowing coals, the following reaction taking place: $\text{C} + \text{S}_2 = \text{CS}_2$.

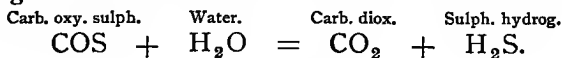
Properties. It is a colorless liquid with a disagreeable odor and high refractive power; insoluble in water. It has marked solvent properties, dissolving iodine, bromine, phosphorus, oils, fats, etc.

Uses. It is used principally as a solvent, and in optics for its high refractive properties.

CARBON OXY-SULPHIDE: COS , $\text{O} = \text{C} \rightleftharpoons \text{S}$.

This compound stands in composition midway between carbon bi-sulphide (CS_2) and carbonic dioxide (CO_2).

Properties. It is an inflammable gas and easily decomposed by water into carbon dioxide and sulphuretted hydrogen. Thus:



SULPHONIC ACIDS. These acids are produced by replacing the hydroxyl of sulphuric acid (H_2SO_4) with a hydrocarbon radical. Thus, *methyl sulphonic acid* has the formula CH_3HSO_3 ; *ethyl sulphonic acid*, $\text{C}_2\text{H}_5\text{HSO}_3$, etc.

A *mercaptan* is an alcohol with oxygen replaced with sulphur.

CHAPTER VII.

NITROGEN SUBSTITUTIONS.

The nitrogen derivatives of the hydrocarbons are numerous and important. From them are formed the *amines*, the *amides*, and the *nitrils*.

The hydrogens in methane may be replaced by the simple element nitrogen, which has an equivalence of

three, forming hydrocyanic acid, HCN, or $\begin{array}{c} \text{H} \\ | \\ \text{C} \equiv \text{N} \end{array}$; by the

compound radical NH_2 , called *amodogen*, which has an equivalence of one, forming *methylamine*, CH_3NH_2 , or

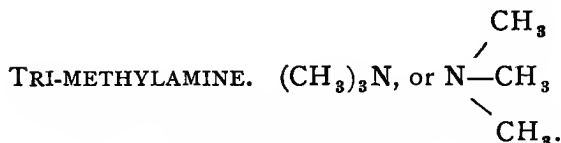
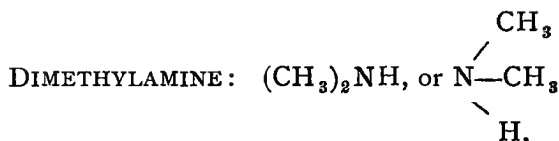
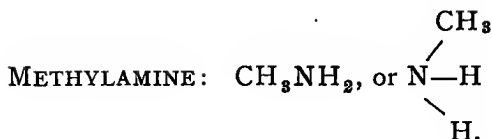
$\begin{array}{c} \text{H} \\ | \\ \text{H}-\text{C}-\text{NH}_2 \\ | \\ \text{H} \end{array}$; or by NH called *imodogen*, which has an

equivalence of two, thus forming CH_2NH , or $\begin{array}{c} \text{H} \\ | \\ \text{NH}=\text{C}-\text{H} \end{array}$.

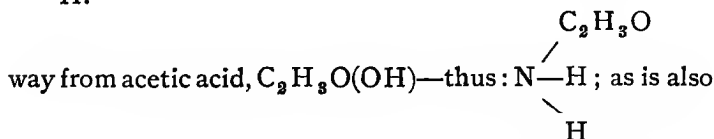
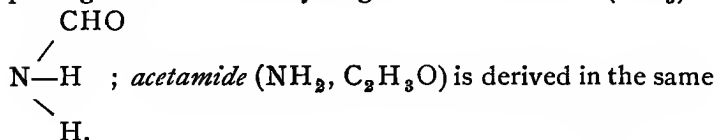
These compounds are much better understood by considering them as derived from ammonia (NH_3).

AMINES. An *amine* is a substituted ammonia with the hydrogens replaced by hydrocarbon radicals.

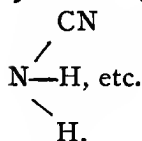
The amines may be primary, secondary, or tertiary, depending upon the number of hydrogens replaced by the hydrocarbons. They resemble ammonia more or less, and unite directly with acids to form salts. Among the most important amines are:



AMIDES are substituted ammonias in which the hydrogens are replaced by acid radicals—the acid minus the hydroxyl (OH). Thus *formamide* (CH_2 , CHO) is derived from formic acid, $\text{CHO}(\text{OH})$, the acid radical CHO replacing one of the hydrogens in ammonia (NH_3)—



cyanamide (CN , NH_2) derived from cyanic acid— $\text{CN}(\text{OH})$,



As the amines may be primary, secondary, or tertiary,

taking the prefixes *mono*, *di*, or *tri*, so may the amides take like prefixes as one, two, or three of the hydrogens in ammonia are replaced by acid radicals.

IMIDES. We have, so far, only considered those substitutions for the hydrogens that have an equivalence of one, but two hydrogens in ammonia may be replaced by diad radicals; such compounds are called *imides*. Thus *carbimide* (NHCO) is such a compound, and may be represented thus:



resented thus: $\text{N} \begin{array}{c} \parallel \\ \text{CO} \end{array} \text{H}$, one hydrogen of the ammonia being replaced by the diad radical carbonyl (CO).

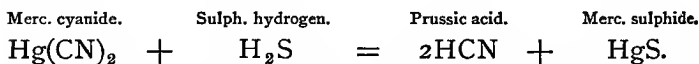
NITRILS. If all the hydrogens of ammonia are replaced by a triad radical we have a class of compounds called *nitrils*. Among the most important nitrils derived from methane is—

HYDROCYANIC ACID: HCN , $\text{N} \equiv \text{CH}$.

Synonym. Prussic acid.

Occurrence. It does not occur free in nature, but is the decomposition product of compounds found in the peach and cherry pits, flowers of the bitter almond, etc.

Preparation. It is best prepared by passing sulphuretted hydrogen (H_2S) over mercuric cyanide $\text{Hg}(\text{CN})_2$. Thus:



Properties. Prussic acid is a colorless liquid, and the most active poison known.

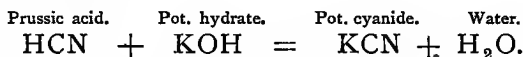
It is soluble in water, alcohol, and ether, and has an odor like peach blossoms. It unites with acids to form salts by the replacement of its hydrogen.

Compounds. Among the most important cyanides are *potassium cyanide* (KCN), *sodium cyanide* (NaCN), *am-*

monium cyanide (NH_4CN), *mercuric cyanide*, $\text{Hg}(\text{CN})_2$, and the *iron cyanides*.

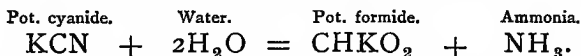
POTASSIUM CYANIDE, KCN.

Preparation. It is best prepared by adding hydrocyanic acid (HCN), to an alcoholic solution of potassium hydrate (KOH). Thus:



The potassium cyanide thus formed being insoluble in alcohol is precipitated.

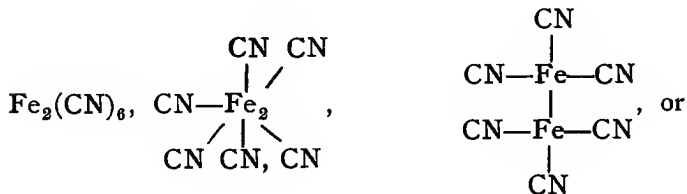
Properties. Potassium cyanide crystallizes in cubes, but deliquesces on exposure to the air. In solution it decomposes rapidly into an amorphous mass called *potassium formate* (CHKO_2), and ammonia NH_3 . Thus:



It has the odor and poisonous properties of hydrocyanic acid. It is also a powerful reducing agent, taking up oxygen readily, thus forming *potassium cyanate* (KCNO).

IRON CYANIDES. These cyanides are seldom found in the separate state on account of their tendency to form double salts. The two principal cyanides of iron are the

ferrous cyanide, $\text{Fe}(\text{CN})_2$, $\text{Fe} \begin{array}{c} \text{CN} \\ / \\ \text{CN} \end{array}$, and *ferric cyanide*,



iron thus taking the equivalence of two or four, or six with use of two atoms to the molecule.

Among the most important double salts are *potassium ferrocyanide* or yellow prussiate of potash, $K_4Fe(CN)_6$; *potassium ferricyanide*, $K_3Fe_2(CN)_{12}$, called red prussiate of potash; and *ferri-ferrocyanide*, $(Fe_2)_2[Fe(CN)_6]_3$, or prussian blue.

CYANIC ACID. Beside the hydrocyanic acid (HCN), in which the hydrogen is united directly with cyanogen (CN), we have *cyanic acid* (HCNO), in which the hydrogen and cyanogen are united by means of oxygen. Thus: $CN-O-H$.

The hydrogen in this acid can be replaced by basic elements or radicals forming salts called *cyanates*, as, for example, *potassium cyanate* (KCNO), *ammonium cyanate* (NH_4 , CNO), *methyl cyanate* (CH_3 , CNO), etc.

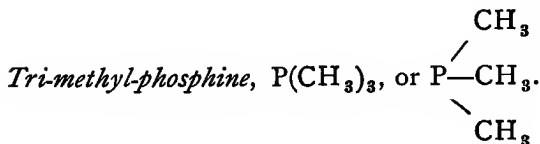
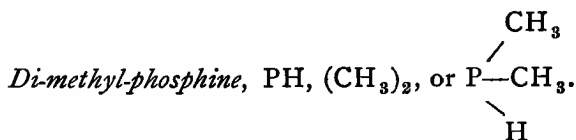
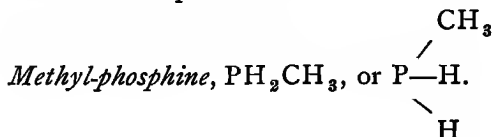
SULPHO-CYANIC ACID. If the oxygen in cyanic acid be replaced by sulphur, *sulpho-cyanic acid* (CNHS) is produced, and from this acid the sulpho-cyanates are formed by replacing the hydrogen with basic elements or radicals. Thus, for example, we have *potassium sulphocyanate* (CNKS), *ammonium sulphocyanate* (CNS, NH_4), etc.

CHAPTER VIII.

PHOSPHORUS AND METALLIC SUBSTITUTIONS.

PHOSPHINES. If phosphorus is substituted for the nitrogen in the amine compounds a new group of compounds is obtained, called *phosphines*.

In the same way as was formed *mono*, *di*, and *tri-methylamine*, we now have by the substitution of phosphorus for the nitrogen, *mono*, *di*, and *tri methyl-phosphine* as thus represented :



PHOSPHINIC ACIDS AND ETHERS.

PHOSPHINIC ACID and **ETHERS** are obtained from phosphoric acid (H_3PO_4) the same way that nitro compounds are obtained from nitric acid (HNO_3), and sulphuric

acids and ethers are obtained from sulphuric acid (H_2SO_4), viz.: in the acid compounds by replacing the hydroxyl (OH) of the acid by a hydrocarbon radical, as methyl (CH_3), and in the ether compounds by thus replacing the hydrogen only. *For example:* The hydroxyls of phos-

phoric acid (H_3PO_4) may be represented thus: $\text{PO} \begin{array}{l} \nearrow \text{OH} \\ \searrow \text{OH} \end{array}$.

Now if one or more of these hydroxyls are replaced by a hydrocarbon radical as methyl (CH_3), a methyl phosphi-

nic acid is formed, as *di-methyl phosphinic acid*, $\text{PO} \begin{array}{l} \nearrow \text{CH}_3 \\ \searrow \text{OH} \end{array}$,

but if the hydrogens alone are thus replaced a compound ether or ester is obtained, as *di-methyl phosphonic ether*,

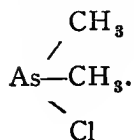
$\text{PO} \begin{array}{l} \nearrow \text{OCH}_3 \\ \searrow \text{OH} \end{array}$. Such esters are sometimes called ester

acids, as one or more hydrogens still remain replaceable.

METALLIC DERIVATIVES.

One or more of the hydrogens in methane may be replaced by a metallic element, thus forming a new set of compounds. For example, *zinc methyl* has the formula $\text{Zn}(\text{CH}_3)_2$ —zinc being a diad, it will take two methyl radicals to satisfy it. Arsenic being a triad, *methyl arsenic* would have the formula $\text{As}(\text{CH}_3)_3$, etc. But beside these single salts, double salts are formed by one or more of the bonds of the metallic element being saturated with other

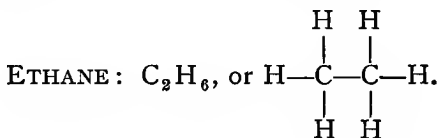
elements, as chlorine. Thus, for example, *di-methyl arsenic chloride* would have the formula $\text{As}(\text{CH}_3)_2\text{Cl}$, or



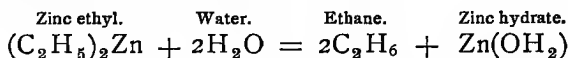
CHAPTER IX.

ETHANE COMPOUNDS.

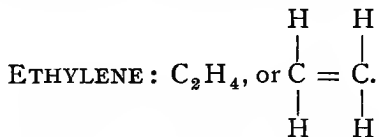
Having considered the methane compounds, we come to the next of the C_nH_{2n+2} series, called ethane; and from it, by taking away two hydrogens, the unsaturated compound ethene or ethylene belonging to the C_nH_{2n} series, and ethine or acetylene (C_2H_2) of the C_nH_{2n-2} series.



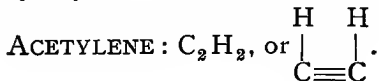
Preparation. It is best prepared by the action of water on zinc ethyl, $Zn(C_2H_5)_2$. Thus:



Properties. Ethane is a colorless gas, combustible and burning with a blue flame.

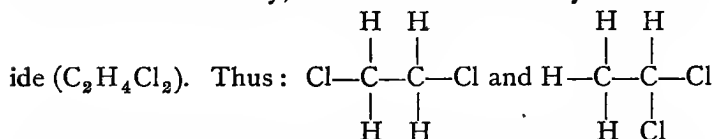


Synonyms. Ethine or olefiant gas.



Synonym. Ethine. Both of these compounds have already been considered in inorganic chemistry.

As ethane is formed by the union of two carbon radicals, and as the hydrogens of either one or both may be replaced by such elements as chlorine, it follows that there may be two isomeric series of compounds formed, having the same formula yet differing in construction. If only one hydrogen be replaced, isomerism is not possible, for the element occupies the same relative position in reference to C and H wherever it is placed; but if two hydrogens be thus replaced, the compounds resulting may be constructed differently, as is the case with ethylene chloride ($C_2H_4Cl_2$).



are isomeric compounds, each having the same formula ($C_2H_4Cl_2$), but entirely different substances.

HALOGEN SUBSTITUTIONS.

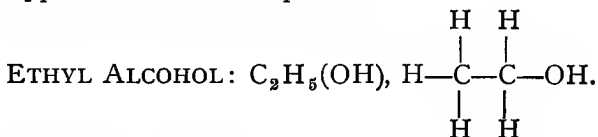
One or more of the hydrogens in ethane may be replaced by the halogen elements, iodine, bromine, or chlorine, thus forming ethyl iodide, bromide, or chloride, which may be either *mono*, *di*, or *tri*.

Among the most important of these compounds are *ethyl mono-chloride* (C_2H_5Cl), *ethyl di-chloride*, more commonly called *ethylene chloride* ($C_2H_4Cl_2$), *ethyl bromide* (C_2H_5Br), and *ethyl di-bromide*, commonly called *ethylene bromide* ($C_2H_4Br_2$). The ethyl chlorides are liquids having a pleasant odor, while the bromides are crystalline solids.

CHAPTER X.

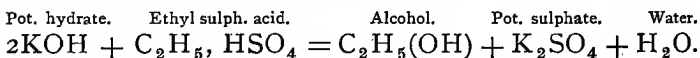
HYDROXYL SUBSTITUTIONS.

The formation of alcohols, aldehydes, and acids have already been explained (page 216) in considering the methane compounds, and as their formation is the same in all the hydrocarbon series, we now go on to examine them as applied to ethane compounds.

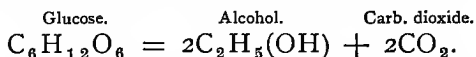


Synonym. Alcohol.

Preparation. Alcohol can be prepared chemically by the action of potassium hydrate (KOH) upon ethyl sulphuric acid C_2H_5, HSO_4 . Thus:



Alcohol is made commercially by fermenting grape sugar (glucose) with yeast, the grape sugar breaking up into alcohol and carbon di-oxide. Thus:



Alcohol can be made from any material containing either starch or sugar, as rice, rye, corn, beets, grapes, etc. By the addition of water, cane sugar ($C_{12}H_{22}O_{11}$) and starch ($C_6H_{10}O_5$) are both converted into glucose

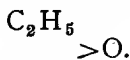
($C_6H_{12}O_6$). The alcohol thus obtained by fermentation is not pure, but contains other alcohols, especially amyl alcohol and water.

The water may be gotten rid of by distillation, the boiling point of alcohol being much below that of water.

Properties. Alcohol is a colorless mobile fluid with an ether-like odor. It boils at $85^\circ C.$, but does not freeze.

It is combustible, burning with a very hot but slightly luminous flame.

It absorbs moisture readily, and extracts the water of crystallization from many salts. It has marked solvent properties readily dissolving iodine, bromine, fats, oil, resins, etc. By uniting with acids alcohol forms compound ethers. With sulphuric acid (H_2SO_4), it forms *ethyl sulphuric acid* or *ester* (C_2H_5, HSO_4); with nitric acid (HNO_3), *ethyl nitric ether* (C_2H_5, NO_3), etc. Salts are formed from these acids by replacing the hydrogen of the acid with basic elements, as potassium, thus forming with ethyl sulphuric acid, *ethyl potassium sulphate* ($C_2H_5 KSO_4$). If alcohol is heated with sulphuric acid it forms (see methyl ether), SULPHURIC ETHER, $C_4H_{10}O$,



or C_2H_5

Synonym. Ether.

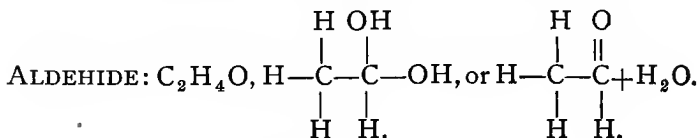
Preparation. Ether is made by heating nine parts of sulphuric acid (H_2SO_4) with five parts of alcohol.

Ethyl sulphuric acid (C_2H_5, HSO_4) is first produced but is afterwards decomposed, splitting up into ether and sulphuric acid. The ether is distilled off with some of the alcohol, and is freed from the latter with caustic lime $Ca(OH)_2$.

Properties. Ether is a colorless mobile liquid with a

pleasant odor, producing insensibility when inhaled. It is combustible, burning with a luminous flame.

Uses. It is used as a solvent and as an anæsthetic.

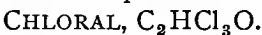


Synonym. Ethyl aldehyde.

Preparation. It is best prepared by the action of chromic acid (H_2CrO_4), on alcohol.

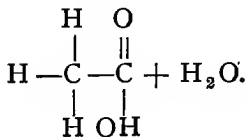
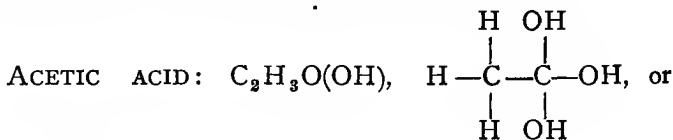
Properties. Aldehyde is a colorless, mobile liquid with a suffocating odor. It is soluble in ether and combustible.

Compounds. Chlorine can be substituted for one or more of the hydrogens in aldehyde, forming compounds, the most important of which is:



Preparation. Chloral is best prepared by the action of chloroform upon alcohol, the alcohol first being converted into aldehyde and afterward into chloral.

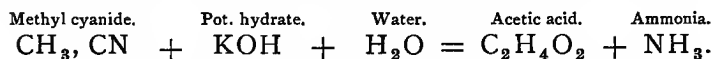
Properties. It exists as a colorless liquid, which added to water forms *chloral hydrate*, $(\text{C}_2\text{HCl}_3\text{O})\text{H}_2\text{O}$, a transparent crystalline substance, having a peculiar odor and biting taste. It is used extensively in medicine.



Synonym. Vinegar.

Occurrence. It is found in many plants and fruits; also in some of the secretions of animals.

Preparation. Acetic acid is prepared by the oxidation of alcohols (acetic fermentation), by the distillation of wood, and chemically by the action of potassium hydrate (KOH) upon methyl cyanide (CH_3, CN). Thus:

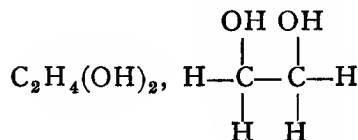


Properties. At ordinary temperatures acetic acid is a colorless liquid having a sharp odor and caustic properties. As it has one replaceable hydrogen (that of the hydroxyl OH), it is mono-basic, and unites readily with bases to form salts, among the most important of which are *potassium acetate* ($\text{KC}_2\text{H}_3\text{O}_2$), *plumbic acetate*, so-called "sugar of lead," $\text{Pb}(\text{C}_2\text{H}_3\text{O}_2)_2$, and *cupric acetate*, or "verdigris," $\text{Cu}(\text{C}_2\text{H}_3\text{O}_2)_2$.

GLYCOLS, ETC.

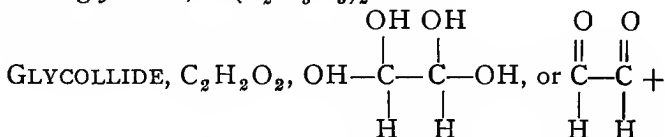
We have so far only considered those alcohols, aldehydes, and acids in which the hydrogens of one hydrocarbon radical forming ethane have been replaced by hydroxyl.

If, however, the hydrogens of both radicals be replaced by hydroxyl, we have formed a new set of alcohols, aldehydes, and acids. Alcohols thus formed are called *glycols*, and the one formed from ethane is ETHYLENE GLYCOL,

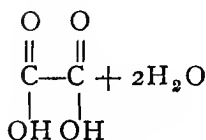
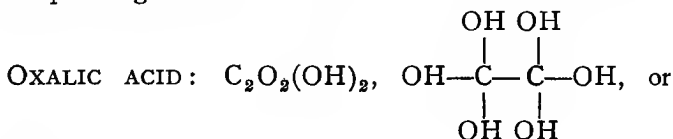


Properties. It is a colorless liquid, quite easily decom-

posed by oxidation into *glycollic* acid $C_2H_4O_3$, which exists in the form of a white deliquescent mass. This acid has one replaceable hydrogen, and forms salts by its union with the basic elements, such as calcium, forming *calcium glycollate*, $Ca(C_2H_3O_3)_2$.



$2H_2O$, is the aldehyde of this order, and oxalic acid the corresponding acid.



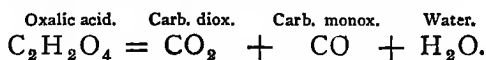
Occurrence. It occurs in many vegetables and fruits in the form of oxalates.

Preparation. It is best prepared by melting sawdust with potassium hydrate (KOH.)

Properties. Oxalic acid as thus prepared crystallizes in transparent prisms.

It is soluble in water and alcohol and is very poisonous.

It readily decomposes by heat into water, carbon dioxide (CO_2) and monoxide (CO). Thus:



Compounds. Oxalic acid is di-basic, having two replaceable hydrogens, $C_2O_2(OH)_2$, and therefore unites with

basic elements to form either acid or neutral salts. Among the most important of these salts are *potassium oxalate* ($K_2C_2O_4$), *acid potassium oxalate* or *potassium hydro-oxalate* (KHC_2O_4), *calcium oxalate* (CaC_2O_4), etc.

By replacing one or both of the hydrogens with hydrocarbon radicals, as ethyl (C_2H_5) or methyl (CH_3) oxalic, acids or esters are formed. Thus we have by the replacement of one hydrogen with ethyl, *ethyl oxalic acid* ($C_2H_5C_2HO_4$) of both hydrogens, *ethyl oxalic ester* or ether $[(C_2H_5)_2C_2O_4]$.

CHAPTER XI.

SULPHUR AND OTHER SUBSTITUTIONS OF ETHANE.

SULPHUR SUBSTITUTIONS.

The sulphur substitutions of ethane are not very important but among them are *ethyl sulphide* $(C_2H_5)_2S$, a colorless liquid having a garlic-like odor; and *ethyl sulphaldehyde* (C_2H_4S) , a substance corresponding in composition to ethyl aldehyde, viz.: two of the hydrogens in ethane being replaced by sulphur instead of the hydroxyl (OH).

NITROGEN SUBSTITUTIONS.

AMINES. By substituting for one or more hydrogens in ammonia (NH_3) the hydrocarbon radical ethyl (C_2H_5) we have formed *mono-, di-, or tri-ethylamine* $C_2H_5NH_2$; $(C_2H_5)_2NH$ and $(C_2H_5)_3N$.

In the same way ethylene amine compounds are formed by replacing the ammonia hydrogens with the compound radical ethylene (C_2H_4), which has an equivalence of two. Thus *ethylene diamine* has the formula $C_2H_4(NH_2)_2$; *di-ethylene diamine*, $(C_2H_4)_2(NH)_2$, etc.

AMIDES. By substituting for one of the hydrogens of ammonia the acid radical of acetic acid $C_2H_3O(OH)$ we have produced *acetamide* (C_2H_5O, NH_2) , a colorless crystalline substance with a peculiar odor. In the same way, by substituting the acid radical of oxalic acid, $C_2O_2(OH)_2$

(oxalic acid having two replaceable hydrogens, hence dibasic), *oxamide* $(C_2O_2(NH_2)_2)$ is produced.

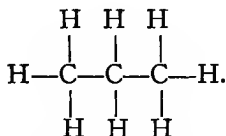
PHOSPHOROUS AND METALLIC SUBSTITUTIONS.

As methyl phosphine (CH_3PH_2) is formed from phosphoric acid (H_3PO_4) by methyl substitutions (see page 229), so in the same way is produced by the substitution of ethyl, *ethyl phosphine* $(C_2H_5PH_2)$, *di-ethyl phosphine* $(C_2H_5)_2PH$, etc. Ethyl, having an equivalence of one, will by uniting with zinc form *zinc ethyl*, $(C_2H_5)Zn$; with arsenic, *tri-ethyl arsine* $(C_2H_5)_3As$; with mercury, *mercury ethyl* $(C_2H_5)_2Hg$, etc.

CHAPTER XII.

PROPANE COMPOUNDS.

Propane compounds are those derived from propane (C_3H_8), which is formed by the union of three hydrocarbon radicals, thus:



Of *propane* but little is known. It belongs to the C_nH_{2n+2} series.

By the extraction of H_2 there is produced a compound belonging to the next series C_nH_{2n} called *propine* or *propylene* (C_3H_6) which exists in the form of a gas. By again extracting H_2 we obtain a compound belonging to the next series C_nH_{2n-2} called *propine* or *allylene* (C_3H_4) which also exists in the form of a gas. As propane is formed by the union of three radicals, it admits of three series of isomeric compounds.

HALOGEN SUBSTITUTIONS.

If a halogen element be substituted for hydrogen in one of the hydrocarbon radicals forming propane, propyl compounds are produced, the most important of which is *propyl iodide* (C_3H_7I).

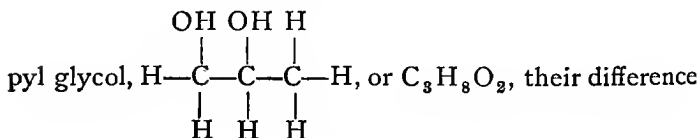
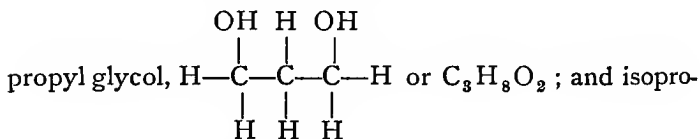
If substituted for the hydrogens in two of the radicals

the compounds resulting are called propylene, as *propylene iodide* ($C_3H_6I_2$), and if substituted for the hydrogens in all three radicals we have allylene compounds, as *allylene bromide* ($C_3H_5Br_3$). As there are more than one hydrogen in each of the radicals, these compounds thus formed may be *mono*, *di* or *tri*, depending upon the number of hydrogens replaced.

CHAPTER XIII.

HYDROXYL SUBSTITUTIONS

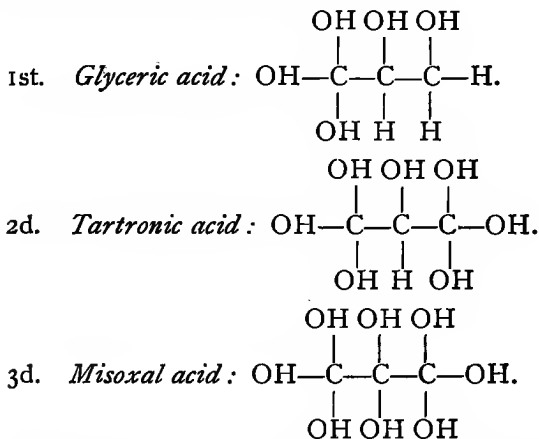
As there are three hydrocarbon radicals forming propane and the hydrogens of either one, two, or three may be replaced by hydroxyl, we have formed three sets of alcohols, aldehydes, and acids. In the first set the hydrogens of only one radical are replaced, in the second set those of two radicals, and in the third set those of all three radicals. Many of these alcohols, aldehydes, and acids are isomeric—having the same chemical formula but differing in their physical and chemical properties. Thus isomerism depends upon the fact that the hydrogens in either of the hydrocarbon radicals forming propane may be replaced by hydroxyl, thus giving the same chemical formula but entirely different substances. Thus, for example, there are two propyl glycols (alcohols); one normal



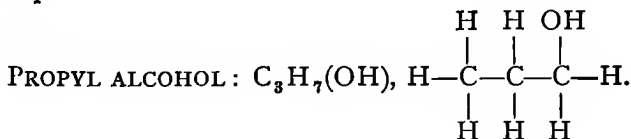
simply depending upon which radical has its hydrogen replaced by OH.

This isomerism is not limited to hydroxyl substitutions but to all substitutions in the hydrocarbon compounds consisting of more than one carbon. In the formation of these three sets of acids, three hydrogens of one hydrocarbon radical must be replaced by OH, but only one or all of the hydrogens in the other radicals need be thus replaced.

Thus, *for example*, in the third set of acids, in which one or more of the hydrogens in all three radicals are replaced by hydroxyl, three acids are formed, depending upon the number of hydrogens replaced as :

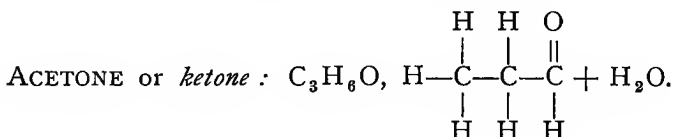


We now come to the consideration of the first set of compounds, in which the hydrogens of only one radical are replaced by hydroxyl. The principal alcohol of this group is :



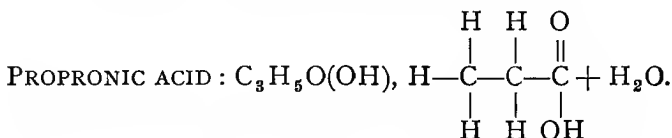
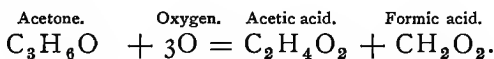
Preparation. It occurs in small amount in the alcoholic fermentation of sugar.

Properties. It is a liquid with an ether-like odor, easily oxidized into the aldehyde of the first class,—



Preparation. It is prepared by the dry distillation of sugar, starch, or salts of acetic acid ($\text{C}_2\text{H}_4\text{O}_2$).

Properties. It is a colorless liquid with a disagreeable odor, breaking up upon oxidation into formic acid, acetic acid. Thus :

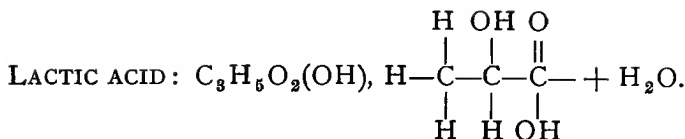


Occurrence. It is found in the blossoms of plants, and in some animal secretions, as sweat.

Preparation. It can be prepared by the oxidation of propyl alcohol or by boiling ethyl cyanide ($\text{C}_2\text{H}_5\text{CN}$) with potassium hydrate (KOH).

Properties. Propionic acid is a liquid having the odor and taste of vinegar. It is a mono-basic acid, and forms salts and esters by substituting for the hydrogen basic elements or hydrocarbon radicals.

PROPYL GLYCOL, $\text{C}_3\text{H}_6(\text{OH})_2$ is an alcohol belonging to the second class, and lactic acid the principal acid.

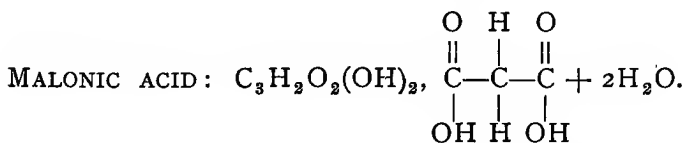


Occurrence. It occurs in sour milk and in the juices of many plants. It is also the product of lactic fermentation of sugar.

Preparation. Lactic acid is best prepared by allowing a solution of sugar to stand several days with putrid cheese and chalk. Calcium lactate, $\text{Ca}(\text{C}_3\text{H}_5\text{O}_3)_2$, is formed, which, when acted upon by sulphuric acid (H_2SO_4), sets free lactic acid.

Properties. It is a syrupy liquid with a very sour taste. Upon distillation it gives off two molecules of water, forming *lactide* ($\text{C}_6\text{H}_8\text{O}_4$).

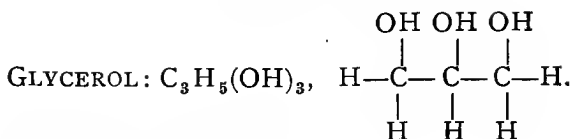
Compounds. Lactic acid is mono-basic, and by union with basic elements forms salts as *magnesium lactate*, $\text{Mg}(\text{C}_3\text{H}_5\text{O}_3)_2$; *potassium lactate*, $(\text{KC}_3\text{H}_5\text{O}_3)$; *zinc lactate* $\text{Zn}(\text{C}_3\text{H}_5\text{O}_3)_2$, etc. By substituting for the hydrogen of the hydroxyl hydrocarbon radicals esters are formed, as *ethyl lactic ester* ($\text{C}_2\text{H}_5, \text{C}_3\text{H}_5\text{O}_3$). By substituting for the hydroxyl, NH_2 , we have the formation of *lactamide* ($\text{NH}_2, \text{C}_3\text{H}_5\text{O}_2$).



This is another acid belonging to the second class.

It is crystalline, soluble in water, and di-basic in character, forming, with basic elements, acids and neutral salts.

There is but one alcohol of the third class, and that is



Synonym. Glycerine.

Occurrence. It is found in nearly all vegetable and animal fats. A little occurs also with the alcoholic fermentation of sugar.

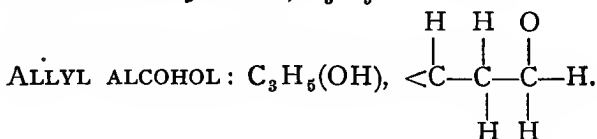
Preparation. It is best prepared by decomposing fats with superheated steam.

Properties. Glycerine is a colorless syrupy liquid with a sweetish taste, soluble in water, and not easily decomposed when pure.

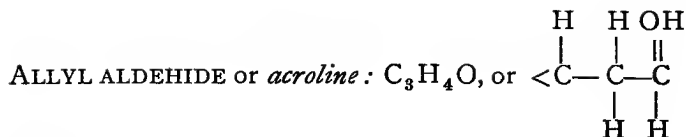
If glycerine is mixed with nitric acid (HNO_3) in the presence of sulphuric acid (H_2SO_4), it forms *nitro-glycerine* or *glycol nitric ester*, $C_3H_5(NO_3)_3$, a violently explosive substance. When this is mixed with infusorial earth it is called *dynamite*. Fats and oils are glycerol esters of glycerides.

ACIDS. There are three acids belonging to the third class, their composition depending upon the number of hydrogens replaced by hydroxyl, none of which, however, are of much importance.

By substituting hydroxyl for the hydrogen of the unsaturated hydrocarbon C_3H_6 of the C_nH_{2n} series we get a new group of compounds called *allyl*, some of which are obtained from *allyl iodide*, C_3H_5I .

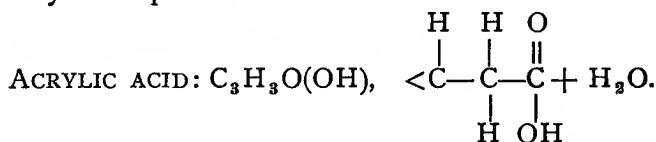


This is a colorless liquid, with a biting odor and taste. It is combustible, burning with a hot flame.



+ H_2O .

This is an oily liquid, with a nasty odor and taste. It readily decomposes.



Acrylic acid is mono-basic, and has a very peculiar, disagreeable odor. Its salts are mostly crystalline, the most important of which is *sodium acrylate* ($NaC_3H_3O_2$).

There are two important oils belonging to the allyl compounds—mustard oil and garlic oil.

Mustard oil, C_8H_8 , NCS is produced from mustard seeds by fermentation.

It is a clear liquid, having the properties of mustard.

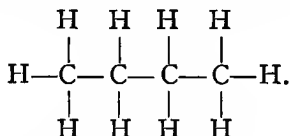
Garlic oil or *allyl sulphide* $(C_3H_5)_2S$ is found in nature in the bulbs of garlics and onions.

It is a clear liquid, with a garlic-like odor.

CHAPTER XIV.

BUTANE COMPOUNDS.

The next of the hydrocarbon series, with the general formula C_nH_{2n+2} , is *butane* (C_4H_{10}), which is a compound of four hydrocarbon radicals expressed thus :

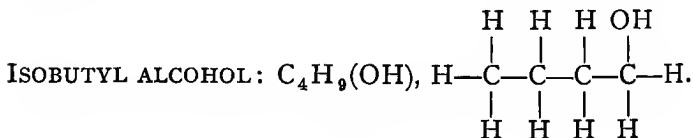


As the hydrogens in any of these four radicals can be replaced by halogens, hydroxyl, etc., many of the resulting compounds are isomeric, as *butyl chloride* (C_4H_9Cl) and *isobutyl chloride* (C_4H_9Cl). The halogen substitutions of butane are numerous but unimportant.

HYDROXYL SUBSTITUTIONS.

As there were three sets of alcohols, aldehydes, and acids formed from propane by hydroxyl substitutions, so there are four sets thus obtained from butane.

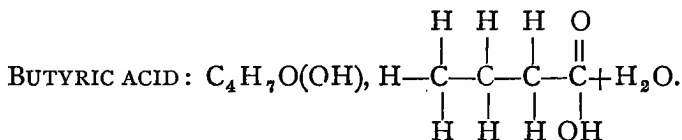
The most important alcohol thus obtained from butane is :



Occurrence. It occurs in the alcoholic fermentation of sugar but in small amount.

Properties. It is a clear liquid with a sharp biting taste, and has an odor resembling fusel oil.

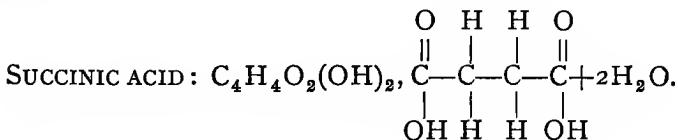
The *aldehydes* of butane are of little importance, but many of the acids are well known.



Occurrence. It occurs with other acids in butter, in sweat, and in the juices of some plants.

Preparation. It is prepared from the lactic-acid fermentation of sugar by a process similar to that of the preparation of lactic acid, except that the fermentation is allowed to proceed further.

Properties. Butyric acid is a colorless sour liquid with an odor resembling vinegar. It is mono-basic in character, forming crystalline salts by its union with basic elements.

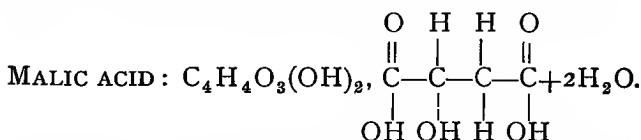


Occurrence. This acid occurs in many plants, in some of the animal secretions, and in amber. It is also a product of the alcoholic fermentation of sugar.

Preparation. It is prepared by the distillation of amber.

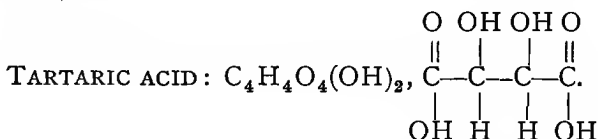
Properties. Succinic acid crystallizes in prisms. It is soluble in water, and has a biting taste. It is di-basic in

character, forming acid or neutral salts by the replacement of one or both hydrogens with basic elements.



Occurrence. It occurs in many sour fruits, and is usually prepared from the ripe berries of the mountain ash.

Properties. Malic acid crystallizes at ordinary temperatures in solid mass. It is soluble in water and has a very sour taste. It is di-basic in character, forming neutral and acid salts.



Occurrence. It occurs in many fruits, especially grapes.

Preparation. Acid tartrates of calcium and potassium occur in solution in young wine, but as the wine grows stronger in alcohol these acid salts, which are insoluble in alcohol, are deposited on the sides of the wine casks. From these masses, called *argol* or *tartar*, the tartaric acid is prepared. It is also artificially produced by the action of nitric acid (HNO_3) on sugar of milk ($\text{C}_{12}\text{H}_{22}\text{O}_{11}$).

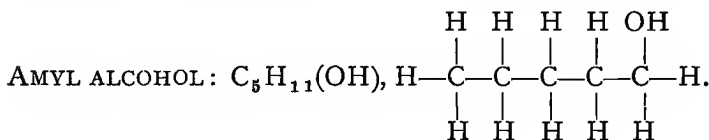
Properties. Tartaric acid occurs in crystals, but is easily soluble in water. It has a sour, pleasant taste, and being di-basic forms acid and neutral salts, some of which are very important. Among the most important tartrates are *acid potassium tartrate* or "cream of tartar" ($\text{C}_4\text{H}_5\text{KO}_6$), *potassium tartrate* ($\text{C}_4\text{H}_4\text{K}_2\text{O}_6$), and *potassium antimonial tartrate* ($2\text{KSbO}, \text{C}_4\text{H}_4\text{O}_6$).

CHAPTER XV.

PENTANE AND HEXANE COMPOUNDS.

PENTANE COMPOUNDS.

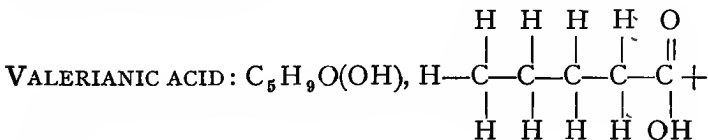
The next of the saturated series C_nH_{2n+2} is *pentane* or *amyl* (C_5H_{12}), and consists of the union of five hydrocarbon radicals. There are but few compounds belonging to this group of any importance. Among them are amyl alcohol and valerianic acid.



Synonym. Fusel oil.

Occurrence. It occurs in the alcoholic fermentation of sugar, and is separated by distillation.

Properties. Fusel oil is a colorless liquid with a burning raw taste and disagreeable odor. It is combustible, burning with a hot flame.



H_2O .

Occurrence. It occurs in the root of the plant valerian, from which it is prepared, and also in putrid cheese.

Properties. It is a liquid with the odor of rotten cheese, and is used extensively in medicine.

It is mono-basic in character, forming salts, the most important of which is *zinc valerianate*, $\text{Zn}(\text{C}_5\text{H}_9\text{O}_2)_2$.

URIC ACID: $\text{C}_5\text{H}_4\text{N}_4\text{O}_3$. This acid probably belongs to the pentane group, but is of complicated composition.

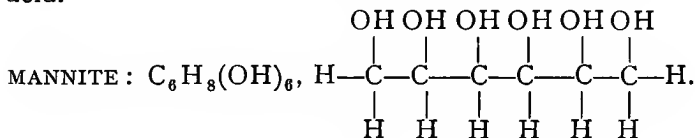
Synonym. Lithic acid.

Occurrence. It forms a normal constituent of urine, and is usually prepared from the urine of snakes, which is composed almost entirely of uric acid.

Properties. Uric acid exists in the form of a white crystalline powder slightly soluble in water. It has two replaceable hydrogens, consequently is di-basic in character, forming neutral and acid salts, the most important of which are *sodium urate* ($\text{C}_5\text{N}_4\text{H}_2\text{Na}_2\text{O}_3$), and *acid potassium urate* ($\text{C}_5\text{N}_4\text{H}_3\text{KO}_3$). Uric acid has many derivatives.

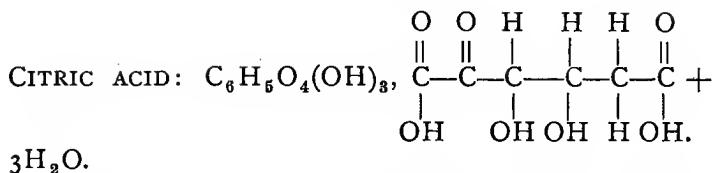
HEXANE COMPOUNDS.

Hexane compounds are not well known or understood. There are several important compounds among this group, however, as hexyl alcohol or mannite and citric acid.



Occurrence. It occurs in large quantities in the vegetable kingdom, especially in "manna," the dried sap of *flaximus ornus*.

Properties. It stands in close relation to sugar. It has a sweet taste, crystallizes in prisms, and is soluble in water.



Occurrence. It occurs in many sour fruits, especially the lemon, from which it is prepared.

Properties. It exists in crystalline masses, which are slightly deliquescent. It is soluble in water, and has a sour, pleasant taste. In solution it readily decomposes.

It is tri-basic, forming salts, the most important of which are *calcium citrate*, $\text{Ca}_3(\text{C}_6\text{H}_5\text{O}_7)_2$, *magnesium citrate*, $\text{Mg}_3(\text{C}_6\text{H}_5\text{O}_7)_2$, and *ferric citrate*, $\text{Fe}_2(\text{C}_6\text{H}_5\text{O}_7)_3$.

CHAPTER XVI.

OILS AND FATS.

There are many higher hydrocarbon compounds of the C H_{2n+2} series than hexane, but most of them are unimportant.

There are several acids, however, belonging to these higher series which are of importance, as they occur in oils and fats. These are *palmetic acid*, $\text{C}_{16}\text{H}_{31}\text{O}(\text{OH})$, *stearic acid*, $\text{C}_{18}\text{H}_{35}\text{O}(\text{OH})$, both of which are solid at ordinary temperatures, and *oleic acid*, $\text{C}_{18}\text{H}_{33}\text{O}(\text{OH})$, a liquid.

FATS and OILS are mostly glycerol esters of these acids, and their composition may be represented by substituting for the hydroxyl hydrogen of glycerol, $\text{C}_3\text{H}_5(\text{OH})_3$, the acid rests of palmetic, stearic, and oleic acids.

The following important glycerol esters or fats are thus obtained :

Palmitin, $\text{C}_3\text{H}_5(\text{C}_{16}\text{H}_{31}\text{O}_2)_3$.

Stearin, $\text{C}_3\text{H}_5(\text{C}_{18}\text{H}_{35}\text{O}_2)_3$.

Olein, $\text{C}_3\text{H}_5(\text{C}_{18}\text{H}_{33}\text{O}_2)_3$.

In the vegetable fats olein is the most important and is fluid at ordinary temperatures. It occurs in olive oil, almond oil, cocoa-nut oil, castor oil, croton oil, etc.

All three of the fats occur in animals.

Butter is a glyceride or ester of butyl and other acids.

Saponification. All fats are decomposed by alkalis

into fatty acids and glycerine. The fatty acids combine with the alkalies to form salts.

These fatty acid salts of potassium and sodium are called *soaps*. *Soft soap* is potash soap, and *hard soap* is soda soap.

SPERMACETI is the palmetic ester of cetyl alcohol, $C_{16}H_{33}(OH)$.

CHAPTER XVII.

CARBOHYDRATES.

Carbohydrates are hydrocarbons, mostly belonging to the hexane compounds, containing hydrogen and oxygen in proportion to form water.

They may be divided into *three* groups. The *first* group, comprising grape sugar, fruit sugar, and galactose, has the general formula $C_6H_{12}O_6$. The *second* group, comprising cane sugar, lactose, and melitose, has the formula $C_{12}H_{22}O_{11}$; and the *third* group, starch, cellulose, dextrine, glycogen, and mucilage, the formula $C_6H_{10}O_5$.

All the carbohydrates are soluble in water, bend the flame of polarized light, are decomposed by heat, leaving carbon, and converted by oxidation into oxalic acid ($C_2H_2O_4$).

GRAPE SUGAR, $C_6H_{12}O_6$.

Synonyms: Glucose, dextrose.

Occurrence. It occurs in nearly all sweet fruits and in honey.

Preparation. It is made from the fruits, and chemically by boiling cane sugar with dilute acids.

Properties. Grape sugar as first obtained is a syrupy liquid, but crystallizes on standing. It is soluble in water and has a sweet taste. It turns the plane of polarized light toward the right, and is fermentable.

When boiled with an alkaline solution of cupric sul-

phate (Cu_2SO_4), the copper becomes oxidized and is precipitated as the red oxide of copper (Cu_2O).

This reaction forms a delicate test for the presence of glucose.

LEVULOSE, $\text{C}_6\text{H}_{12}\text{O}_6$.

Synonym. Fruit sugar.

Its occurrence, preparation, and properties are the same as glucose, but can be distinguished from it by turning the plane of polarized light toward the left, and being less easily crystallized.

GALACTOSE, $\text{C}_6\text{H}_{12}\text{O}_6$.

Preparation. It is prepared by boiling milk sugar with dilute acids. Its properties are the same as glucose.

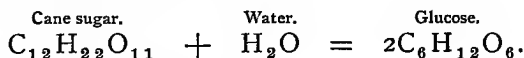
CANE SUGAR, $\text{C}_{12}\text{H}_{22}\text{O}_{11}$.

Synonym. Saccharose.

Occurrence. It occurs principally in the juices of sorghum, sugar cane, sugar beet, and maple, and is prepared from them by evaporation.

Properties. It crystallizes, is soluble in water, has a very sweet taste, and polarizes toward the right.

By heating with dilute acids it takes up water and is converted into glucose. Thus:



LACTOSE, $\text{C}_{12}\text{H}_{22}\text{O}_{11}$.

Synonym. Milk sugar.

Occurrence. It occurs in mammals' milk, from which it is prepared.

Properties. It crystallizes in rhombic-shaped prisms, is soluble in water, and has a sweet taste, having the general properties of cane sugar.

STARCH, $\text{C}_6\text{H}_{10}\text{O}_5$.

Synonym. Amylum.

Occurrence. It occurs abundantly throughout the vegetable kingdom, but is found especially in grains and potatoes, from which it is prepared.

Properties. It consists of fine white granules, their shape depending upon the kind. It is without taste, and insoluble in cold water.

It is converted first into dextrine and then into glucose by dilute acids, by dry heat, and by *diastase* (a ferment in germinating grain). Iodine unites with starch in solution, forming a deep blue color, thus affording a delicate test for amylum.

GLYCOGEN, $C_6H_{10}O_5$.

Occurrence. It occurs in all livers, from which it is prepared.

Properties. Glycogen is a yellowish-white powder, soluble in water, and changed into glucose by dilute acids and ferments. With iodine it turns a claret color.

DEXTRINE, $C_6H_{10}O_5$.

Synonym. British gum.

Preparation. It is prepared from starch by adding dilute nitric acid (HNO_3), and then rapidly drying.

Properties. Dextrine is an amorphous white substance (without any reaction with iodine, soluble in water, and rapidly converted into glucose by means of ferments and acids.

CELLULOSE, $C_{18}H_{30}O_{15}$.

Synonyms: Woody fibre, cotton.

Occurrence. It forms the skeleton and plant cells of wood and plants.

Properties. As usually prepared it is a white mass, insoluble in water. When dissolved with sulphuric acid (H_2SO_4) and precipitated by the addition of water, it is called *amyloid*. It is this amyloid that gives the peculiar

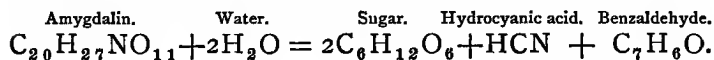
appearance to "parchment paper." If cellulose (cotton) be treated with one part nitric acid (HNO_3) and three parts sulphuric acid (H_2SO_4), a violent explosive called *gun-cotton*, $\text{C}_{18}\text{H}_{21}(\text{NO}_3)_9\text{O}_{15}$, is formed.

Gun-cotton dissolved in ether is called *collodion*, $\text{C}_{18}(\text{NO}_3)_9\text{H}_{22}\text{O}_{15}$.

GLUCOSIDES. There is a large number of substances occurring in the vegetable kingdom closely allied to the carbohydrates, called *glucosides*. They are usually compounds of dextrose, combined with one or more other organic substances.

By boiling with dilute acids, alkalies, or by ferments they split up into sugar and the other constituents of which they are composed.

Amygdalin, $\text{C}_{20}\text{H}_{27}\text{NO}_{11}$, is the glucoside found in bitter almonds, cherry and peach pits, etc., and can be split up by the ferment—*emulsion*—into its constituents, dextrose, hydrocyanic acid, and benzaldehyde. Thus:



CHAPTER XVIII.

FERMENTATION.

Some substances, when undergoing decomposition or decay, have the property of setting up decomposition in other substances when added to them. The decaying substance is called a *ferment*, the substance decomposed *fermentable*, and the process *fermentation*.

Different ferments set up different kinds of fermentation, but do not themselves add any elements to the products of fermentation.

If the products of fermentation are sweet-smelling, the process is called pure fermentation; but if accompanied by foul odors, putrefaction.

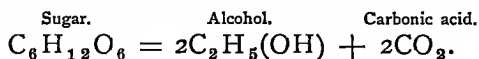
Ferments are of two kinds, decomposable organic compounds and organized bodies. Belonging to the first class are albuminous substances as *diastase*, a substance formed from germinating grain from the decomposition of gluten; *emulsin* a substance occurring in almonds; and the *animal ferments* occurring in animal secretions, as saliva, pancreatic and gastric juices, etc.

Belonging to the second class of organized ferments are the *yeast plant lactic-acid ferment*, etc. As most ferments are vegetable growths, they must be supplied with proper food for their development. This food is found in the albuminous principles occurring in the fermentable substance.

Most ferments require for their development oxygen,

and a temperature between 40° and 90° F. Some substances undergo spontaneous fermentation, but this is due to the *sporules* or seeds of the ferment which float in the air finding their way into these substances and then propagating.

There are five principal fermentations—*alcoholic*, *acetic*, *lactic*, *butyric*, and *mucous*, the most important of which is the alcoholic. The alcohol ferment is yeast, the fermentable substance sugar, and the principal products of fermentation, alcohol and carbonic-acid gas. Thus:



ALCOHOLIC BEVERAGES.

BEER is prepared from germinating grain, usually barley. During this process, called malting, a ferment, *diastase*, is produced, which acts on the starch of the grain, converting it into sugar. Hops are added to give it flavor, and yeast to produce the alcoholic fermentation. The fermentation is never allowed to run its full course. *Porter*, *ale*, and *stout* are very similar to beer, but differ in the rapidity, temperature, and time of fermentation, and porter by containing caramel.

WINE is made from fermented grape juice, which will undergo spontaneous fermentation if exposed to the air, owing to the presence of vegetable albumen, which undergoes decomposition and acts as a ferment on the grape sugar. *Effervescent* wines are bottled before fermentation is completed. *Dry* or *acid* wines contain but little or no unchanged sugar.

During fermentation of grape juice, *argol*, or acid potassium tartrate, is deposited on the sides of the casks, owing to the fact that this salt is insoluble in the alcohol

which is being produced, but found in solution in the grape juice.

WHISKEY and SPIRITS are usually made from grain, but a large quantity of raw grain is added to germinating grain or malt, the diastase converting the starch into sugar. Fermentation is pushed as far as possible with yeast and the product distilled.

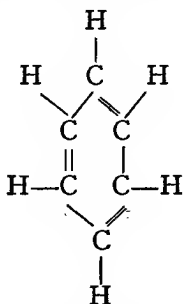
CHAPTER XIX.

AROMATIC GROUP.

BENZINE.

As the *fatty group* of compounds was derived directly or indirectly from *methane* benzene (CH_4), so has the *aromatic group* also a starting-point in *benzine* (C_6H_6).

BENZINE is supposed to belong to the unsaturated group of hydrocarbons having the general formula $\text{C}_n\text{H}_{2n-6}$, and graphically expressed by the chain or ring formula



As one or more hydrogens in methane can be replaced by halogens, hydroxyl, acid radicals, amidogen, etc., so may the hydrogens in benzine be likewise replaced. It is a curious fact, however, if only one hydrogen in benzine be thus replaced by elements or atomic groups, but one compound can be formed, in other words one hydrogen substitution allows of no isomerism. This does not hold

true, however, if two or more hydrogens be thus replaced.

BENZINE, C_6H_6 .

Synonym. Benzol.

Preparation. All organic compounds heated to a red heat yield benzine ; hence it is formed in the manufacture of illuminating gas, and obtained from the coal tar by distillation.

Properties. Benzine is a clear liquid with an aromatic odor and taste. It has a low boiling point, and is readily combustible, burning with a very smoky yellow flame.

It has strong refractive properties, and is used in the manufacture of aniline and aniline colors.

CHAPTER XX.

BENZINE DERIVATIVES.

It is not necessary to point out a great many of the benzine derivatives but a comparatively few of them being of much importance. We have already seen that one or more of the benzine hydrogens may be replaced by halogen elements, hydroxyl, amidogen, acid radicals, hydrocarbon radicals, etc., hence it will be but necessary to consider the most important of these compounds thus formed by substitution.

There are but few HALOGEN SUBSTITUTIONS of importance, and among them may be mentioned *mono-chlor-benzine* (C_6H_5Cl) and *mono-iodo-benzine* (C_6H_5I). Among the most important ACID DERIVATIVES of benzine is *nitro benzine* (C_6H_5, NO_2), formed by replacing the acid radical of nitric acid (the acid minus hydroxyl) for one benzine hydrogen. It is prepared by adding nitric acid (HNO_3) to benzine and then precipitating the nitro-benzine by water. Thus produced it is a heavy yellow oil with a pleasant odor—used in perfumery under the name of oil of merbane.

HYDROXYL SUBSTITUTIONS.

There are many important hydroxyl substitutions in benzine, and the compounds thus produced are called *phenols*.

CARBOLIC ACID, C_6H_5OH .

Synonyms: Phenol, hydroxyl benzine.

Occurrence. It is one of the principal constituents of coal tar, from which it is prepared.

Properties. Carboic acid crystallizes in clear needles, but gradually turns red on exposure to the light. It has a peculiar dead smell, a sweetish taste, and caustic properties. It is slightly soluble in water, readily in glycerine.

Uses. It is used in medicine as a disinfectant, and in the production of aniline colors. Although phenol is really an alcohol it also acts as a mono-basic acid, uniting with basic elements to form salts and with alcohol rests to form esters with the replacement of hydrogen.

Thus we have *sodium phenate*, C_6H_5NaO , *lead phenate*, $(C_6H_5O)_2Pb$, *phenyl ethyl ester*, C_6H_5O, C_2H_5 , etc. If three of the benzene hydrogens are replaced by the acid radical NO_2 and one of the hydrogens by hydroxyl OH , there is formed PICRIC ACID, $C_6H_2(NO_2)_3OH$.

PICRIC ACID, $C_6H_2(NO_2)_3OH$.

Synonym. Tri-nitro-phenol.

Preparation. It is prepared by heating phenol with nitric acid (HNO_3).

Properties. Picric acid crystallizes in yellow leaves. It is soluble in water and has a very bitter taste. It forms salts with basic elements, the most important of which is *potassium picrate*, $C_6H_2(NO_2)_3KO$.

Uses. It is used for dyeing purposes.

If three benzene hydrogens are replaced by hydroxyl several isomeric compounds are produced, the most important of which is *pyrogalllic acid*, $C_6H_3(OH)_3$, a crystalline white substance soluble in water and with a bitter taste. It is a good oxydizing agent.

AMIDOGEN SUBSTITUTIONS.

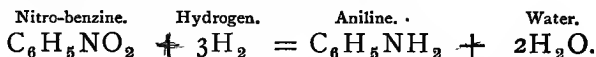
Among the most important amidogen derivatives of benzene is aniline.

ANILINE, $C_6H_5NH_2$.

Synonym. Amido-benzine.

Occurrence. It occurs largely in coal tar.

Preparation. It may be prepared in a number of ways, as by the dry distillation of indigo from coal tar by ignition, etc., but it is generally made by reducing nitro-benzine ($C_6H_5NO_2$) with iron filing and acetic acid ($C_2H_4O_2$), the reduction being thus represented :



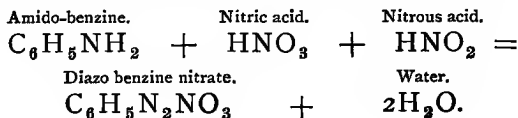
Properties. Aniline is a yellowish liquid turning brown on exposure to the light. When brought in contact with calcium hypochlorite $Ca(ClO)_2$, it turns a violet color. It unites with acid to form salts.

One or both of the amido-hydrogens may be replaced by hydrocarbon radicals, forming compound anilines, as *ethyl aniline* (C_6H_5, NH, C_2H_5); or by acid rests as CHO , the acid rest of formic acid $CHO(OH)$, forming anilides, as *formanilide* (C_6H_5, NH, CHO).

Uses. It is used principally in the manufacture of aniline colors and dyes.

NITROGEN SUBSTITUTIONS.

AZO-BENZINES. If hydrogen benzine be replaced by nitrogen we have formed a group of compounds called *azo-benzines*. The most important of these compounds are *azo-benzine*, $(C_6H_5)_2N$, *diazo-benzine*, $C_6H_5N_2$ and *diazo-benzine nitrate*, $C_6H_5N_2NO_3$, which is produced by the action of nitrous and nitric acid on amido-benzine. Thus :



This is a crystalline substance, decomposing with explosive violence on exposure to heat or percussion.

INDIGO GROUP.

There is a class of compounds called the *indigo group*, which are benzene derivatives but of complex composition. This group starts from a glucoside called *indican*, which occurs in a number of plants. This substance, when boiled with acids, decomposes into sugar and *indigo white*, and the latter, by exposure to the air, turns into *indigo blue*.

INDIGO BLUE, $C_{16}H_{10}N_2O_2$.

Preparation. It is best obtained in the pure state from commercial indigo, which consists of a number of substances, by sublimation.

Properties. Indigo blue is a blue, odorless, and tasteless powder, insoluble in water and alcohol.

When heated with alkalis in presence of reducing agents, as sulphuretted hydrogen (H_2S), it takes up hydrogen and passes into a soluble and colorless substance called *indigo white* ($C_{16}H_{12}N_2O_2$), which is largely used in indigo dyeing. On exposure to the air indigo white is slowly converted into indigo blue. Indigo blue, when treated with oxidizing agents, as nitric or chromic acid, takes up oxygen and is converted into *isatin* ($C_{16}H_{10}N_2O_4$), which exists in the form of reddish-brown, odorless prisms, slightly soluble in water, but readily in alcohol.

Both indigo blue and isatin when treated with potassium hydrate (KOH) are converted into aniline.

CHAPTER XXI.

HYDROCARBON SUBSTITUTIONS OF BENZINE.

If one or more of the benzene hydrogens are replaced by hydrocarbon radicals a number of important compounds are formed and among them is :

TOLUENE : C_6H_5 , CH_3 .

Synonym. Methyl benzene.

Preparation. It may be prepared by heating organic compounds to a high temperature and then distilling, or chemically by heating mono-brom-benzene and methyl iodine with sodium. Thus :

Mono-benzene.	Meth. iod.	Sodium.	Toluene.	Sod. bromide.	Sod. iodide.
C_6H_5Br	$+ CH_3I$	$+ Na_2$	$= C_6H_5, CH_3$	$+ NaBr$	$+ NaI.$

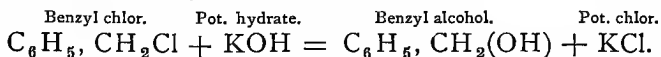
Properties. Toluene resembles benzene in all its properties.

BENZYL COMPOUNDS.

One or more of the hydrogens in toluene may be replaced by halogens, hydroxyl, amidogen, etc., thus forming an enormous number of new compounds, but the most important of which are those formed by replacing the hydrogen of the hydrocarbon radical in toluene; such substitutions are called *benzyl compounds*. By thus replacing one hydrogen with chlorine we have formed *benzyl-chloride* (C_6H_5, CH_2Cl); with hydroxyl, *benzyl alcohol* (C_6H_5, CH_2OH), etc.

BENZYL ALCOHOL : $C_6H_5, CH_2(OH)$.

Preparation. It is prepared by treating benzyl chloride with potassium hydrate. Thus:



Properties. Benzyl alcohol is a colorless liquid with a pleasant odor. It forms esters by replacing the hydroxyl hydrogen with acid rests, as benzyl acetic ester ($\text{C}_6\text{H}_5, \text{CH}_2\text{O}, \text{C}_2\text{H}_3\text{O}$), etc.

If two hydrogens in toluene instead of one be replaced by hydroxyl, a molecule of water is given off and *benzyl aldehyde* is formed.

BENZYL ALDEHIDE: $\text{C}_6\text{H}_5, \text{CHO}$.

Synonyms: Benz-aldehyde, bitter almond oil.

Preparation. It is prepared from a glucoside, occurring in bitter almonds, called *amygdalin*.

Properties. It is a colorless liquid with the odor and taste of bitter almonds. It is not poisonous, as the hydrocyanic acid (HCN) occurring in bitter almonds is eliminated by the process of preparation. If three hydrogens in toluene be thus replaced by hydroxyl, *benzoic acid* is produced, a molecule of water being given off.

BENZOIC ACID: $\text{C}_6\text{H}_5, \text{CO}(\text{OH})$.

Occurrence. It occurs in many gums, from which it is prepared by sublimation.

Properties. Benzoic acid crystallizes in colorless leaflets, slightly soluble in water, and with an aromatic taste and odor. It is mono-basic in character, uniting with bases to form salts, as *sodium benzoate*, $\text{C}_6\text{H}_5\text{CO}_2\text{Na}$.

BENZOIC-ACID COMPOUNDS.

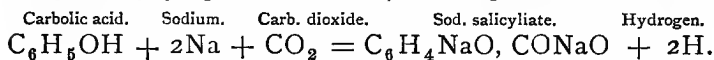
One or more hydrogens in benzoic acid, ($\text{C}_6\text{H}_5\text{CHO}_2$) may be replaced by chlorine amidogen, hydroxyl, etc., thus forming a new set of compounds, many of which are

important. Thus, if one hydrogen is replaced by chlorine, we have *mono-chlor-benzoic acid* (C_6H_4Cl, CHO_2); by NO_2 , *nitro-benzoic acid* ($C_6H_4NO_2, CHO_2$); by NH_2 *amido-benzoic acid* ($C_6H_4NH_2, CHO_2$); by OH , *salicylic acid* (C_6H_4OH, CHO_2), etc.

SALICYLIC ACID: $C_6H_4(OH), CO(OH)$.

Occurrence. It occurs as a principal constituent of winter-green oil.

Preparation. It is prepared from carbolic acid (C_6H_5OH) by heating it with sodium, and then passing carbon dioxide through the mixture. In this way *sodium salicyliate* ($C_6H_4NaO, CONaO$) is also produced. Thus:



Properties. Salicylic acid crystallizes in prisms, which are slightly soluble in water, and have a bitter taste but no smell. It acts either as a mono- or di-basic acid uniting with alkalies, with the replacement of both hydrogens, as *sodium salicyliate* ($C_6H_4NaO, CONaO$).

Uses. It is used principally as an antiseptic, and in medicine.

If three of the benzene hydrogens in benzoic acid are replaced by hydroxyl, *gallic acid* is formed.

GALLIC ACID, $C_6H_2(OH)_3CHO_2$.

Preparation. It is usually prepared from its ester, *tannic acid* ($C_{14}H_{10}O_6$).

Properties. Gallic acid crystallizes in fine needles, is soluble in water, and has a very bitter astringent taste.

Although it usually acts as a mono-basic acid, any or all of the four hydroxyl hydrogens may be replaced by basic elements forming salts.

Tannic acid is an important ester of gallic acid.

TANNIC ACID, $C_{14}H_{10}O_9$.

Synonym. Tannin.

Occurrence. It occurs in many plants, as nut-galls, sumach, etc., from which it is usually prepared by extraction with alcohol and ether.

Properties. Tannin is freely soluble in water, has a very bitter taste, and is astringent. Animal skins precipitate tannin from its solution, converting them into leather.

HIPPURIC ACID, $C_9H_9NO_3$.

Occurrence. This acid is of complex composition, but is a derivative of benzoic acid. It occurs in the urine of herbivora, and is the result of eating substances rich in benzoates.

Properties. Hippuric acid crystallizes in needles, and is but slightly soluble in water.

It has a salty, bitter taste, and is mono-basic in character.

We have so far considered only the hydrocarbon derivatives of benzene in which one hydrogen has been replaced.

Not only may one hydrogen be thus replaced, but hydrocarbon radicals may be substituted for two, three, or four hydrogens, each forming a new set of compounds. But few of these compounds are of importance, many of them either not being understood or are unknown.

Those compounds resulting from the substitution of hydrocarbon rests, forming benzene derivatives with eight carbon atoms, are called XYLENES, from *xylene*, $C_6H_4(CH_3)_2$; those forming benzene derivatives with nine carbon atoms, CUMENS, from *cumene*, $C_6H_5(CH_3)_3$; and those containing ten carbon atoms, CYMENES, from *cymene*, $C_6H_2(CH_3)_4$.

There are two *cumene* compounds which deserve attention, viz.: *cinnyl alcohol* and *cinnamic acid*, formed by re-

placing one of the hydrogens in benzene with allyl alcohol (C_3H_5OH), and acrylic acid C_3H_3O , (OH) radicals respectively.

CYNNAL ALCOHOL: C_6H_5 , $C_3H_4(OH)$.

Synonym. Phenol allyl alcohol.

Properties. It is a colorless oil, which gradually, upon standing, crystallizes into needles. It is but slightly soluble in water, and upon oxidation is converted into CINNAMIC ALDEHYDE (C_6H_5 , C_2H_3O), a colorless liquid, prepared from cinnamon oil, which contains it largely.

CINNAMIC ACID: C_6H_5 , $C_3H_2O(OH)$.

Occurrence. It occurs in liquid storax, and is separated from it by heating with sodium carbonate (Na_2CO_3). It also occurs in old cinnamon oil, probably from oxidation of cinnamic aldehyde.

Properties. Cinnamic acid crystallizes in prisms, which are soluble in water, and have a bitter taste and pleasant odor. It has one replaceable hydrogen, hence is monobasic, uniting with bases to form salts, and with hydrocarbon rests to form esters.

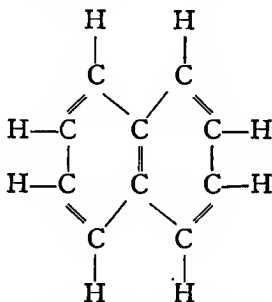
CHAPTER XXII.

AROMATIC GROUPS OF ORGANIC COMPOUNDS.

We come now to the consideration of a number of important aromatic groups of compounds, some having their composition well known, while others have constitutions not known with certainty.

NAPHTHALINE GROUP.

This group has its starting-point in *naphthaline* ($C_{10}H_8$), a substance occurring largely in coal tar. In composition it is a compound benzene—that is, formed by the union of two benzene rings. Thus:



It crystallizes in white leaflets, and has a peculiar odor and hot taste. It is but slightly soluble in water, but readily in alcohol.

One or more hydrogens may be replaced by halogens, acid radicals, hydroxyl, etc., thus forming naphthalene

derivatives. The hydroxyl derivatives are called *naphthols* from *naphthol*, $C_{10}H_7(OH)$.

ANTHRACINE GROUP is derived from *anthracine* ($C_{14}H_{10}$), a substance also occurring largely in coal tar. It crystallizes in leaflets and is but slightly soluble in water.

ALIZARIN GROUP has its starting-point in *alizarin* ($C_{14}H_8O_4$), a coloring matter obtained by fermenting the madder root and other plant roots.

It crystallizes in yellowish prisms, is insoluble in water, but readily in alkaline solution, from which it is precipitated by basic elements forming salts. It is used extensively in dyeing.

CAMPHOR GROUP. Common camphor ($C_{10}H_{16}O$) is the principal member of this group, and is obtained from the gum of the camphor tree. It is a gum-like substance, slightly soluble in water and readily in alcohol. It has a pleasant and burning taste, is combustible, burning with a very smoky, yellow flame. It unites directly with bromine without the replacement of hydrogen, forming brom-camphor ($C_{10}H_{16}Br_2O$).

TURPENTINE GROUP. To this group belongs the *essential* oil, having the composition $C_{10}H_{16}$. They are obtained from plants by steam distillation, and are usually divided into two groups, those containing oxygen and those free from oxygen. Among the former are *caraway oil*, *clove oil*, *rue oil*, *rose oil*, *bitter-almond oil*, *anise oil*, etc. while among the latter are *lemon oil*, *orange oil*, *turpentine oil*, *amber oil*, etc. There are also three essential oils containing sulphur, viz., *mustard oil*, *spoonwort oil*, and *leek oil*.

RESIN GROUP. Resins are obtained from plants, together with the essential oil. If they remained dissolved

in the essential oils they are called *balsams*, but if mixed with gum they are known simply as *resins*. Among the principal balsams may be mentioned *copaiba balsam*, *peru balsam*, *tolu balsam*, and *shellac*.

Caoutchouc, or "india-rubber," is one of the principal resins. It is obtained from the juice of trees growing in India. When heated with sulphur it becomes "vulcanized," which renders it more elastic even when cold. On higher heating it is converted into "vulcantine" or "hard rubber." *Gutta-percha* is a resin like india-rubber and obtained in the same way.

Amber and *asphalt* are called the hard or "fossil" resins.

CHAPTER XXIII.

ALKALOIDS.

Alkaloids are nitrogenous substances occurring in plants and sometimes called *organic bases* on account of their strong basic properties. They are almost insoluble in water but freely soluble in alcohol. They give soluble salts with acids. The alkaloids are precipitated from solutions of their salts with alkalies and tannic acid.

All the alkaloids contain carbon, nitrogen, and hydrogen ; some with, others without, oxygen. When no oxygen is present the alkaloids are liquids, but with oxygen they are mostly solid and crystalline.

Alkaloids are prepared by treating the powdered plants containing them with weak acids, and then distilling if the alkaloids are volatile. If not, the alkaloid bases are precipitated with alkalies from their acid solution.

The alkaloids all have a powerful action on the animal organism, hence are mostly poisonous and are used largely as medicines.

The following is a list of the most common alkaloids :

CONINE, $C_8H_{15}N$, exists already formed in the hemlock.

NICOTINE, $C_{10}H_{14}N_2$, is obtained from tobacco leaves.

MORPHINE, $C_{17}H_{19}NO_3$,

CODEINE, $C_{18}H_{21}NO_3$, and

NARCOTINE, $C_{22}H_{33}NO_7$, are all obtained, with eighteen or nineteen others, from the juice of the poppy (opium).

QUININE, $C_{20}H_{24}N_2O_2$, is obtained, with three or four other alkaloids, from the bark of the cinchona tree.

STRYCHNINE, $C_{21}H_{22}N_2O_2$, and BRUCINE, $C_{23}H_{26}N_2O_4$, are both obtained from the seeds of the *strychnos nux vomica*.

ATROPINE, $C_{17}H_{23}NO_3$, is found in the deadly nightshade.

ACONITINE, $C_{30}H_{47}NO_7$, is found in the root of the purple monk's hood.

ESERINE, $C_{15}H_{21}N_3O_2$, and

PHYSOSTYGMINE are both obtained from the calabar bean.

COCAINE, $C_{17}H_{21}NO_4$, occurs in the leaves of the cocoa.

CHAPTER XXIV.

ANIMAL CHEMISTRY.

There are a number of complex substances, many of them with unknown composition, occurring in animal tissues and fluids, and are hence usually described under the head of *animal chemistry*.

The organic compounds all contain oxygen, nitrogen, carbon, and hydrogen, and some of them sulphur.

As these substances are properly treated of under physiology, a mere mention of them will be given here.

Among these substances are albumen, fibrin, casein, etc., and may be classified under the following divisions:

INORGANIC SUBSTANCES.

Water, H_2O .

Sodium chloride, $NaCl$.

“ phosphate, Na_2HPO_4 .

“ bi-phosphate, NaH_2PO_4 .

“ sulphate, Na_2SO_4 .

“ carbonate, Na_2CO_3 .

Potassium chloride, KCl .

“ phosphate, K_2HPO_4 .

“ carbonate, K_2CO_3 .

“ sulphate, K_2SO_4 .

Calcium phosphate, $Ca_3(PO_4)_2$.

“ carbonate, $CaCO_3$.

Magnesium phosphate, $\text{Mg}_3(\text{PO}_4)_2$.

“ carbonate, MgCO_3 .

Besides these inorganic principles, there are always found in larger or smaller amount, in the animal tissues and fluids, traces of iron, silica, and fluorine ; these also are constant constituents.

HYDROCARBONS.

Glycogen, $\text{C}_6\text{H}_{10}\text{O}_5$.

Glucose, $\text{C}_6\text{H}_{12}\text{O}_6$.

Lactose, $\text{C}_6\text{H}_{12}\text{O}_6$.

FATS.

Stearin, $\text{C}_3\text{H}_5(\text{C}_{18}\text{H}_{35}\text{O}_2)_3$.

Palmatin, $\text{C}_3\text{H}_5(\text{C}_{16}\text{H}_{31}\text{O}_2)_3$.

Olein, $\text{C}_3\text{H}_5(\text{C}_{18}\text{H}_{33}\text{O}_2)_3$.

Cholesterin, $\text{C}_{26}\text{H}_{44}\text{O}$.

Cholesterin is a crystalline substance found principally in the bile, from which it sometimes crystallizes, forming gall-stones.

It is also found in the blood, spleen, nerves, etc.

ALBUMINOUS PRINCIPLES.

These form an important group of substances found in the animal body, and all present the following peculiarities: First, they are *hygroscopic*; second, they are *coagulable*; and third under favorable circumstances they undergo *putrefactive* changes.

Albumen, found principally in the plasma of the blood.

Casein, an albuminous principle in milk.

Fibrinogen, found in blood plasma.

Paraglobulin, obtained from the blood.

Myosine is obtained from muscular tissue, and causes "rigor mortis" by coagulation after death.

Syntonin, or acid albumen, produced by the action of the gastric juice on albumen.

Peptone, produced by the further action of gastric juice on albuminous matter.

Mucosine or "mucus," found in many glandular secretions.

Collagin, found in bones, tendons, etc., and yields "gelatine" on boiling.

Chondrine, albuminous principle in cartilage.

Elasticine, from yellow elastic tissue.

Keratine, an albuminous substance containing sulphur; found in hair, nails, etc.

ANIMAL FERMENTS.

There are substances that seem to cause by their presence *catalytic* transformations, that is, they produce changes in substances in which they come in contact, without entering into chemical combination with them.

Ptyalin, ferment of the saliva.

Pepsin is the gastric-judge ferment.

Pancreatin and *trypsin*, the pancreatic ferments.

Fibrin or blood ferment causing the coagulation of the blood.

ANIMAL COLORING MATTERS.

Hemoglobin, the coloring matter of the blood.

Melanin, that of the skin, eyes, etc.

Bilirubin and *Biliverdin*, that of the bile, and

Urochrome, the coloring matter of the urine.

CRYSTALLIZABLE NITROGENOUS MATTER.

These substances differ from the albuminous principles by being crystallizable. They are :

Lecithin, found in the blood, liver, etc.

Cerebrin, obtained principally from the brain and spinal cord.

Leucin, found largely in the spleen.

Sodium glycocholate and *sodium taurocholate* are both ingredients of the bile. *Creatin*, found principally in muscular tissue.

Creatinine, *urea*, *urates*, and *hippurates* are all found in the urine, and are the result of tissue metamorphosis.

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